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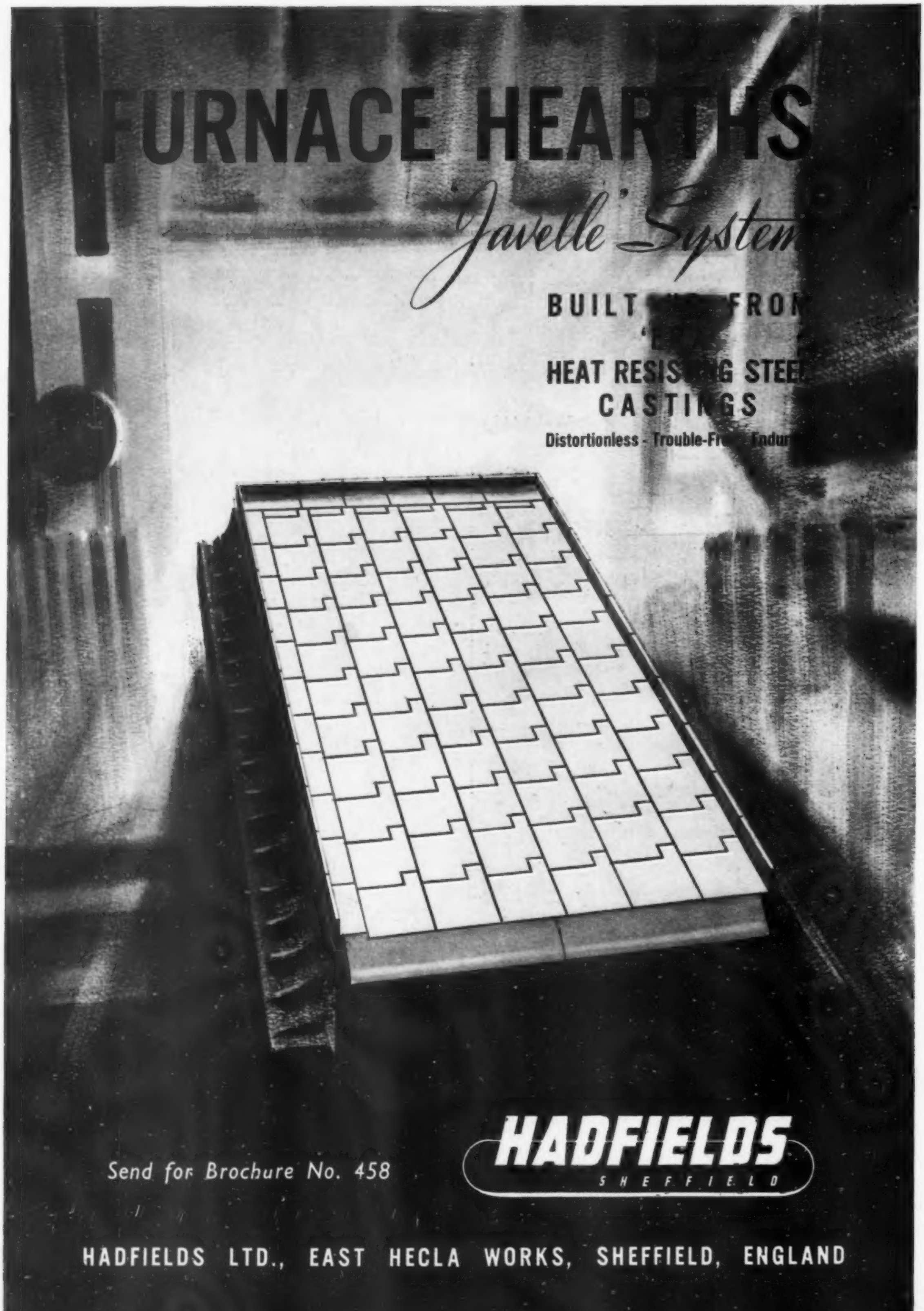
METALLURGIA

THE BRITISH JOURNAL OF METALS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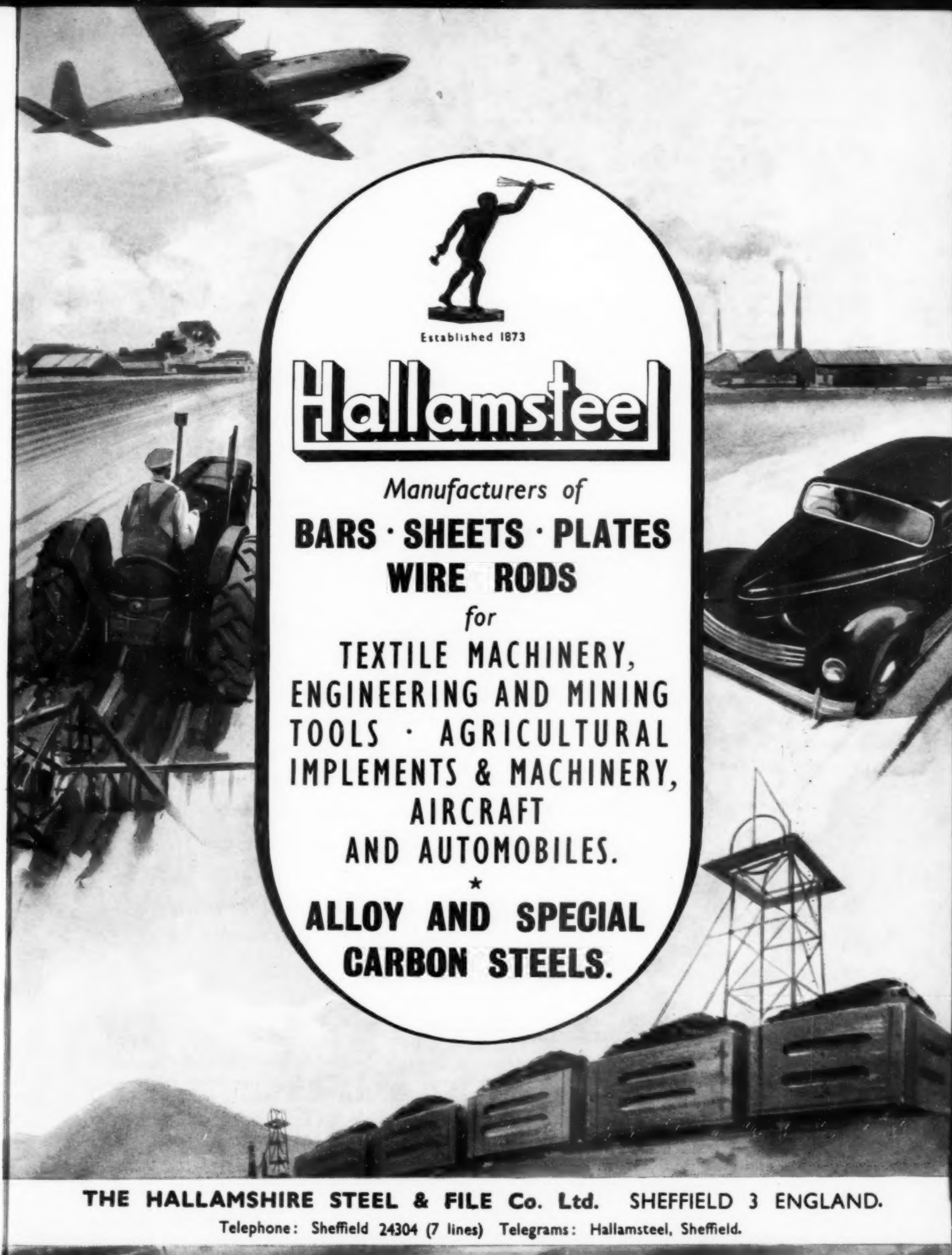
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Data Sheet 1

SPECIFICATIONS AND COMPOSITIONS FOR GENERAL ENGINEERING PURPOSES

B.S. En No.	Type	C%	Mn%	Ni%	Cr%	Mo%
FOR HARDENING AND TEMPERING						
13	Mn-Ni-Mo	·15/·25	1·4/1·8	0·4/0·7		·15/·35
16	Mn-Mo	·25/·40	1·3/1·8			·20/·35
17	Mn-Mo	·30/·40	1·3/1·8			·35/·55
19	1% Cr-Mo	·35/·45	·5/ ·8		·9/1·5	·20/·40
24	1½% Ni-Cr-Mo	·35/·45	·45/ ·7	1·3/1·8	·9/1·4	·20/·35
25	2½% Ni-Cr-Mo	·27/·35	·5/ ·7	2·3/2·8	·5/ ·8	·40/·70
26	2½% Ni-Cr-Mo	·36/·44	·5/ ·7	2·3/2·8	·5/ ·8	·40/·70
27	3% Ni-Cr-Mo	·25/·35	·7max.	3·0/3·75	·5/1·3	·20/·65
28	3½% Ni-Cr-Mo	·25/·40	·7max.	3·0/4·5	·75/1·5	·20/·65
29	3% Cr-Mo	·15/·35	·65max.	·4max.	2·5/3·5	·30/·70
30B	4¼% Ni-Cr-Mo	·26/·34	·4/ ·6	3·9/4·3	1·1/1·4	·20/·40
100	Low Alloy	·35/·45	1·2/1·5	·5/1·0	·3/ ·6	·15/·25
110	Low Ni-Cr-Mo	·35/·45	·4/ ·8	1·2/1·6	·9/1·4	·10/·20
160	2% Ni-Mo	·35/·45	·3/ ·6	1·5/2·0		·20/·35
FOR CASE HARDENING						
34	2% Ni-Mo	·14/·20	·3/ ·6	1·5/2·0		·20/·30
35	2% Ni-Mo	·20/·28	·3/ ·6	1·5/2·0		·20/·30
39B	4¼% Ni-Cr-Mo	·12/·18	·5max.	3·8/4·5	1·0/1·4	·15/·35
320	2% Ni-Cr-Mo	·14/·20	·4/ ·7	1·8/2·2	1·8/2·2	·15/·25
325	Low Ni-Cr-Mo	·17/·22	·45/·65	1·5/2·0	·4/ ·6	·20/·30
FOR NITROGEN HARDENING						
40A	3% Cr-Mo	·10/·20	·4/·65	·4max.	2·9/3·5	·40/·70
40B	3% Cr-Mo	·20/·30	·4/·65	·4max.	2·9/3·5	·40/·70
40C	3% Cr-Mo-V (V ·10/·30)	·30/·50	·4/ ·8	·4max.	2·5/3·5	·70/1·20
41	1½% Cr-Al-Mo (Al ·9/1·3)	·18/·45	·65max.	·4max.	1·4/1·8	·10/·25

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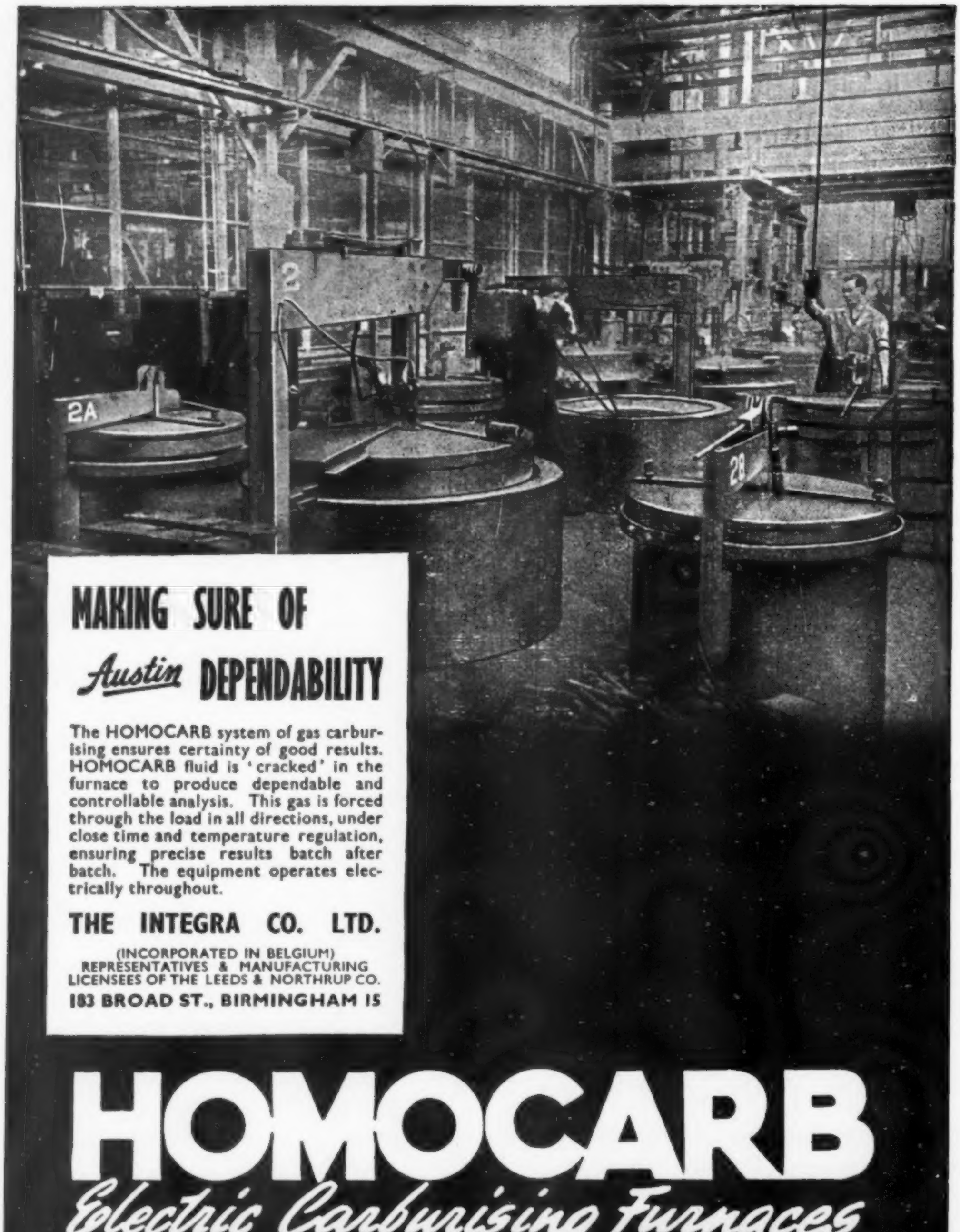
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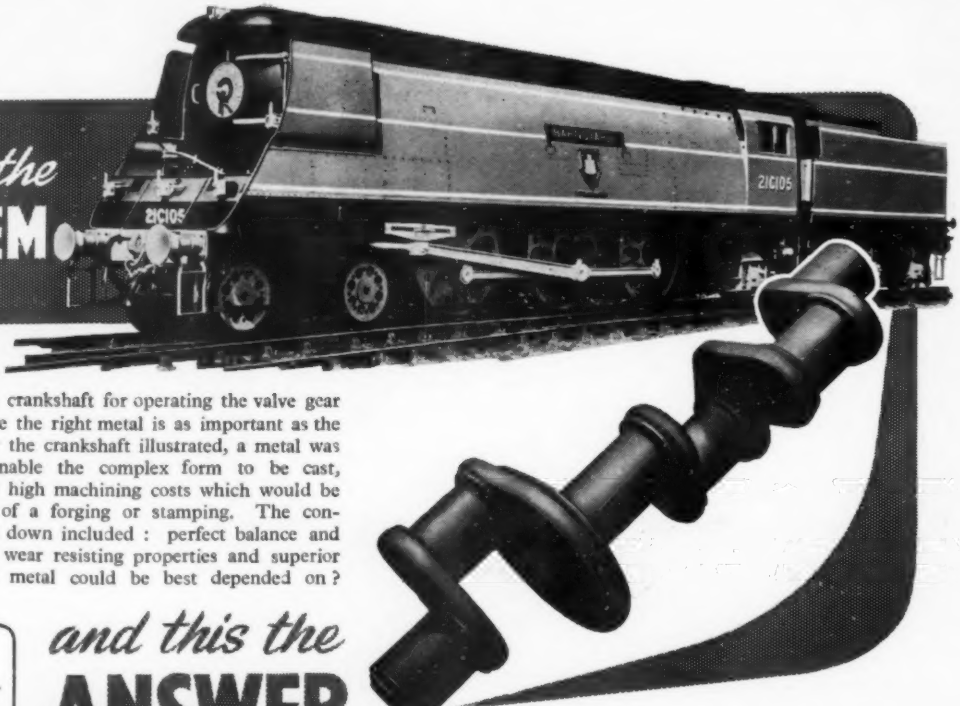

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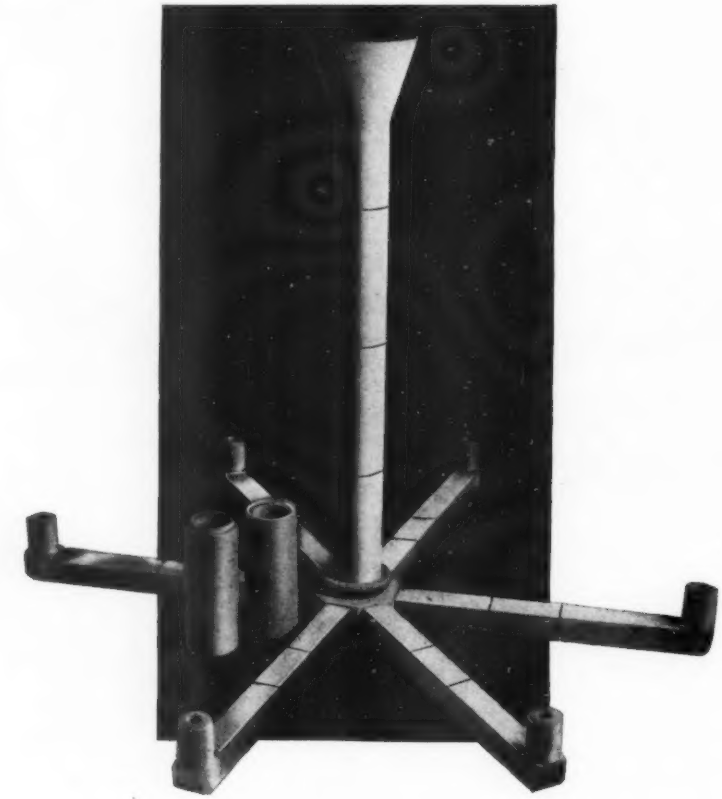

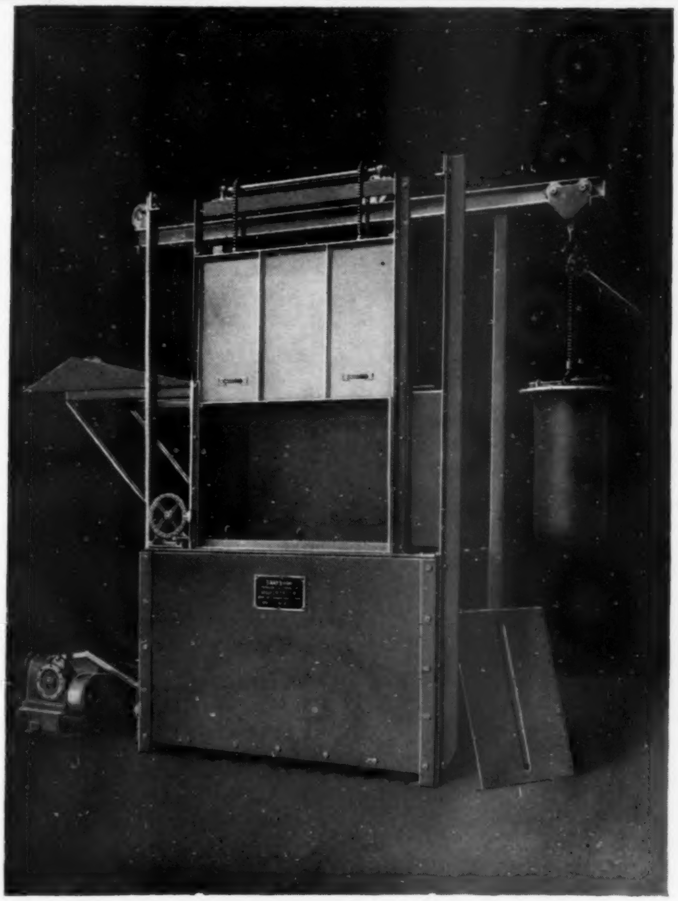

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METALLURGIA

The British Journal of Metals

INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING THE "METALLURGICAL ENGINEER."

MAY 1949 Vol. XL No. 235

Britain Displays Her Products

THE British Industries Fair which opens simultaneously at Olympia, Earl's Court and Castle Bromwich on May 2nd and remains open until May 13, will compare favourably, both in number of exhibitors and quality of exhibits, with any previous year. Indeed, so great has become the demand for accommodation at the several centres that the space available is now too small and it would seem that in future exhibitions further extensions will be necessary, preferably by the addition of a fourth building to house, say, ironmongery. However, there is little doubt that the present effort will be the largest ever staged despite the activities of industries to meet production targets.

At Olympia the exhibits consist mainly of manufactured goods, but one section, that embracing scientific instruments, will have considerable interest for many readers. Not so many years ago, it will be remembered, many scientific instruments, used in the metallurgical industries, were imported ; to-day, as a result of great progress in this field, British instruments compare favourably with the world's best and a very substantial export trade has been developed. Earl's Court, as in former years, is primarily concerned with textiles and the range and quality of fabrics to be exhibited will exceed previous exhibitions. The heavy industries, which stage their exhibits at Castle Bromwich, is the largest of the three and includes the engineering and electrical industries as well as ironmongery and several other sections.

Because of the fields covered by the exhibits at Castle Bromwich, which are more directly concerned with the metallurgical industries, a pre-review of exhibits in this section is presented elsewhere in this issue. The object of this is to provide readers with a brief outline of some of the outstanding features in order that they may be able to make full use of the somewhat limited time they have available when visiting the Fair. On the other hand it will be especially useful to those unable to undertake a visit, since it focusses attention on a number of developments within the metallurgical field. While every effort has been made to obtain the latest information concerning products on view, it will be appreciated that many exhibitors had not completed their arrangements, regarding particular exhibits, at the time of going to press, hence omissions have been unavoidable.

British exports in the years that have passed have been built on sound principles and in consequence a considerable measure of confidence exists between manufacturers and overseas buyers. We believe that a continuation of this business confidence is a valuable contribution, and one of the solutions, to many of the world's problems, and the facilities the Fair affords of bringing together potential buyers and manufacturers is of great assistance in fostering confidence. Many exhibitors, in addition to providing a worthy display, make arrangements to open their works to visitors, and this idea could usefully be adopted more widely, because overseas buyers, in particular, generally appreciate the opportunity of seeing the manufacture of those products in which they are interested. Only by establishing confidence can we hope to achieve the increased exports desired, and this is the real object of the Fair, which provides opportunities for forming new contacts that are invaluable to manufacturers and buyers alike.

The Fair, of course, is an incentive to trade ; it is the assembling of the greatest concentration of British products before a very large number of home and overseas buyers. Behind this drive for increased world trade, however, is ingenuity and scientific and technical skill which has been developed to ensure that the products of British industry continue to maintain the high prestige for quality and workmanship earned over many years. Visitors can be assured that in regard to scope and quality of finished product, the exhibits are not exceeded by any other country, and their cost, having regard to reliable service, will compare favourably with that of similar products made elsewhere.

In the metallurgical field the continued development and improvement in the standard of manufacture of iron and steel, as well as of non-ferrous materials, has introduced new applications. This has involved new designs for many finished products, and improvements in, or the development of, new tools and equipment to meet the special needs of each product, and to facilitate the production of each article. The exhibits indicate development and improved technique in production from crude pig or ingot through the various processes of manufacture to the assembled and finished article.

Although new developments of alloy and special steels are few in number, their importance is great. Advances in low-alloy engineering constructional steels, steels for use at elevated temperatures, gas turbine steels, tool steels, and materials for permanent magnets, are considerable, some evidence of which will be noted on various stands. Much development work in the production and application of copper and its alloys has been accomplished or put into operation since the last Fair. Progress has been made in techniques applied in casting, fabricating, plating and finishing. Visitors will note particularly the wider use of aluminium and its alloys. In the fabrication of these materials Britain continues to maintain and improve her international position. Technically, this industry is ahead of other countries, particularly in the application of aluminium in structural engineering and building, and indirect exports have already reached appreciable levels and trade trends indicate that these will increase in importance. Observant visitors will appreciate that the metallurgical industries have made considerable headway and the flare for ingenuity, which has always been associated with British industry, is still a characteristic of manufactures and is contributing to the urge for greater effort in serving the needs of potential customers at home and abroad.

Iron and Steel Educational Drive

THE difficulty in obtaining the right type of recruits is a source of anxiety to many industries and since the war many educational schemes have been put into operation, either by individual concerns, associations, or by particular industries. In connection with a scheme developed by the British Iron and Steel Federation, iron and steel exhibitions in steel producing areas throughout the country are being held, the central feature of which is an education and training drive. The big industrial centres visited are Middlesbrough, Sheffield, Manchester, Scunthorpe, Glasgow, Bilston, Cardiff and Swansea. The first exhibition of the series opened at Middlesbrough early in April, Sheffield has followed and at the time of writing it is being held in the College of Technology, Manchester. The remaining centres are being visited in turn.

At each centre, educational authorities, representatives of managements of companies and of trades unions are invited to attend the official openings and, in addition to viewing the exhibition, opportunities are provided for informal discussions. Schools in each area and educational experts are invited to the exhibitions, each of which will last about a week.

At the official opening of the exhibition at Manchester, Mr. J. E. James, Chairman of Lancashire Steel Corporation, had much to say about steel production, particularly of plans for a rapid expansion in the production of Lancashire steel. He said his Company was determined to make iron and steel more prominent among the industries of the County. New equipment to be installed at the Irlam Works would make it one of the most complete units for its size in the world. Masters and men have decided that the steel furnace of the future must work as continuously as the coke ovens or blast-furnaces. This would effect a revolution in steel making and recruits of the right type are needed to be trained and assist in developing this vital industry.

A central Committee has prepared a training scheme for young workers up to the age of twenty-one years and this will be operated by an Area Organisation covering the whole country, which has been set up for that purpose. The scheme provides for all young people entering the industry. Its main purpose is to ensure introductory training to bridge the gap between school and industry, the provision of skilled instruction in each task youngsters perform within the works and, as far as possible, release for one day a week for vocational and non-vocational training by local education authorities. It has been decided that, owing to the wide variation in trades and circumstances between the various localities, the scheme should be applied on a local basis and this will be arranged by Area Committees.

Co-operative schemes will be provided to meet the difficult problem of the small firm employing a few boys only and in order to assist Area Committees in carrying out this task, the Federation has arranged to employ fully qualified Training Officers on their behalf. At the same time, the many firms in the industry who already employ Training Officers are co-operating fully by making available their experience and advice to all other members of the Federation.

Interchange visits of students and technicians between this country and overseas steel producing countries will be continued and increased. Educational films, film strips and instructional booklets are being produced as part of the campaign.

Advance in Steel Prices

THE recent statement by the Ministry of Supply that subsidies paid on iron and steel, to meet the excess cost of imported finished steel and the import duties on pig iron and steel, would be discontinued from April 1st, has necessitated considerable advance in iron and steel prices. The Governments decision to pass on to industry losses previously borne by the Exchequer will have caused considerable dismay in many industries, particularly the shipbuilding industry. The increased prices, which are reproduced from the current issue of *Monthly Statistical Bulletin* published by the British Iron and Steel Federation, show that they vary from 10s. 3d. per ton for foundry pig iron to 89s. per ton for tinplates ; for most products, however, they are between £2 and £3 per ton.

NEW AND OLD PRICES
(Per ton except for tinplate)

	New Maximum Basic Price			Old Maximum Basic Price*			Increase		
	£	s.	d.	£	s.	d.	£	s.	d.
Basic Pig Iron	9	17	6	9	5	0	0	12	6
Hematite Pig Iron	11	16	6	10	2	6	1	14	0
Foundry Pig Iron	10	0	6	9	10	3	0	10	3
Soft Basic Billets	17	1	6	14	7	6	2	14	0
Heavy and Medium Sections	19	13	6	17	1	6	2	12	0
Plates	20	14	6	17	16	6	2	18	0
Rails	19	2	6	16	16	6	2	6	0
Wire Rods	21	2	3	18	10	0	2	12	3
Re-Rolled Bars	22	6	0	19	10	0	2	16	0
Re-Rolled Sections	21	16	0	19	0	0	2	16	0
Hot Rolled Hoop and Strip	23	1	0	20	5	0	2	16	0
Black Sheets	28	16	0	25	1	0	3	15	0
Tinplate (per box)	2	1	6	1	17	5½	0	4	0½
Cold Rolled Strip	31	15	6	29	11	6	2	4	0
Bright Steel Bars	31	2	3	29	13	0	1	9	3
Wire	28	0	0	25	17	6	2	2	6
Forging Fagots	17	16	0	15	8	0	2	8	0
Alloy Steel Billets	25	6	9	22	17	3	2	9	6
Colliery Arches	23	0	3	19	16	6	3	3	9

* The prices shown are not, after deduction in certain cases of existing "loyalty rebates." On the Iron and Steel Board's recommendation the industry has agreed to the abolition of all loyalty rebates and the new prices in the Iron and Steel Control Order are net prices.

The fact that the Government appreciate the task imposed on some industries in maintaining competitive prices in the export markets does not alleviate the position. The increased prices is a great blow to shipbuilding and many types of structural work in which steel plays a major part. As Mr. R. Gillespie of the British Tanker Co., stated recently, this rise in the cost of steel has brought shipowners to the position where they cannot afford to commit themselves to new orders far ahead with the danger of upward costs. Already shipbuilding and ship repairing centres are experiencing difficulties due to rising costs and the growing unemployment in these centres indicate that the keen competition resulting is having its effect. The people in these areas remember the bleak 1930's and naturally regard as evil anything that interferes with their livelihood.

It should, of course, be realised that the iron and steel industry's costs have risen during the past 12 months. Of these increases, the most important is the additional cost of foreign ore. Other items include coal and wages, both of which have advanced. The general review of prices and margins, however, has been such that the aggregate effect of these cost increases, in particular the increased wage costs, are not passed on to the consumer ; in some sections of the trade the higher output has helped in this direction. But as a result of the upward trend of costs, the margins for depreciations and profit available to producers of the primary steel products have tended to decline.

In many industries the increased cost of iron and steel will be small in relation to the cost of the final products and it is likely that efforts will be made to concentrate more on these industries at the expense of those industries whose products consume a relatively large proportion of these materials.

Sand Cast Nickel Alloys

For Corrosion and Heat-Resisting Service

By W. H. Richardson, B.Sc., A.I.M.

Langley Alloys, Ltd., Slough

An ever increasing demand for materials of construction possessing improved corrosion resistance and mechanical properties has resulted in the development of such a multitude of "corrosion-resistant" "acid-resistant" "stainless" and "rustless" alloys that the task of selecting the most suitable material can be, to say the least, somewhat onerous. The following information on an important group of corrosion-resistant alloys is presented in the hope that it will alleviate this position in being of assistance to chemical engineers and others when designing plant which is required to operate for long periods under the most arduous conditions of corrosion.

THERE is no doubt that nickel has been an important constituent of certain alloys for many centuries. Thus it has been established that cupro-nickel alloys were used for coinage over 2,000 years ago, whilst many centuries have elapsed since the Chinese first produced an alloy known as "Packfong" which was the forerunner of our nickel-silver.

However, it was not until 1751 that the element nickel was isolated, and it did not become available as a commercial metal until the middle of the 19th century. At that time almost the entire production of nickel was used in the manufacture of alloy steels and German silver. For production of the latter alloy, it was the practice to employ a cupro-nickel alloy which was obtained directly by smelting certain copper-nickel sulphide ores. Owing to the small demand, this practice of smelting directly to cupro-nickel was discontinued until, in 1905, the International Nickel Company produced a nickel-copper alloy, which was found to possess exceptionally good properties as smelted, and which could, therefore, be used as an engineering material without further alloying. This alloy, which was given the name of Monel,* in honour of the then President of the International Nickel Company—Mr. Ambrose Monell—contained 60–70% nickel and was, therefore, the first nickel-base alloy to be produced on a commercial scale, and it was destined to become one of the most important alloys of this class.

The use of chromium as an alloying element in nickel, was suggested by Marsh in 1903, when he discovered two very important properties of these alloys—viz., high electrical resistivity and excellent resistance to oxidation at elevated temperatures. Alloys of this type were made commercially available in 1908, but only as wire and ribbon for electric heating elements, and it was not until the 1920's that Inconel,* an alloy containing 14% chromium and 6% iron, was developed as a material suitable for the production of castings for heat and corrosion resisting service.

During the same period, it was noted that certain alloys of nickel and molybdenum possessed a high resistance to corrosion, by non-oxidising acids, such as hydrochloric. This discovery initiated a number of researches into the properties and constitution of nickel-molybdenum alloys, but it was not until 1938 that useful information was published. In that year, Grube and Schlecht[1] reported the results of an investigation of the nickel-molybdenum diagram, including corrosion tests in hydrochloric acid. The following year, McCurdy[2] presented the results of an intensive research, which indicated the superiority of certain nickel-molybdenum and nickel-silicon alloys for specific corrosion-resisting applications. The compositions suggested by McCurdy are shown in Table I.

TABLE I.—APPROXIMATE COMPOSITIONS OF THE ALLOYS INVESTIGATED BY McCURDY

Alloy	% Ni	% Mo	% Cr	% Fe	% Si	% W	% Cu
A	Bal.	20	—	20	—	—	—
B	Bal.	30	—	5	—	—	—
C	Bal.	19	15	5	—	5	—
D	Bal.	—	—	—	10	—	3

Alloys of this type were, until recently, produced in the U.S.A. only under the name Hastelloy† but similar materials, known as the Langalloy‡ series of alloys, have now become available in this country.

CONSTITUTION AND MECHANICAL PROPERTIES OF NICKEL ALLOY CASTINGS

The nominal compositions and mechanical properties considered in this article are shown in Table II.

Pure nickel is a very useful material for many corrosion resisting applications, but in common with many other pure metals, it does not readily lend itself to the production of sound sand castings. However, the addition of small proportions of silicon and manganese improve the fluidity and other casting properties to such an extent that sound, pressure tight castings can be produced without materially reducing the corrosion resistance. A small amount of carbon may also be incorporated in this alloy, the result of this being to accentuate the effect of silicon and manganese in promoting good casting properties. Another important benefit derived from the

* Registered Trade Mark of Henry Wiggin & Co., Ltd.

1 Grube G. and Schlecht, H. *Z. Electrochem.*, 44, 413 (1938).
2 McCurdy, F. T., "Nickel-Molybdenum-Iron and Related Alloys," A.S.T.M. Reprint 1939.
† Registered Trade Mark of Haynes Stellite, Co.
‡ Registered Trade Mark of Langley Alloys, Ltd.

TABLE II.—PROPERTIES OF SAND CAST NICKEL ALLOYS.

	Monel (Ordinary grade)	Monel (2·75% Silicon)	Monel (3·75% Silicon)	Nickel	Inconel	Langalloy 4R	Langalloy 5R	Langalloy 6R
Max. Stress, tons/sq. in.	25–35	33–40	40–45	20–28	28–36	32–36	32–36	25–35
Yield Point, tons/sq. in.	12–16	18–24	40–45	9–13	12–18	20–25	20–25	25–35
Elongation% on 2 in.	16–40	8–15	0–4	15–35	15–30	5–10	8–12	0–3
Brinell Hardness	100–150	180–220	230–300	100–125	120–180	200–250	180–220	350–400
Izod Impact, ft./lb.	40–80	30–40	0–4	50–80	40–80	10–15	10–15	—
Modulus of Elasticity in Tension, lb./sq. in.	26×10^6	—	21×10^6	30×10^6	31×10^6	30×10^6	28×10^6	28×10^6
Modulus of Elasticity in Torsion, lb./sq. in.	$9 \cdot 5 \times 10^6$	—	—	11×10^6	—	—	—	—
Poisson's Ratio	0·32	—	—	0·31	—	—	—	—
Density, lb./cu. in.	0·318	0·313	0·308	0·320	0·307	0·335	0·320	0·280
Coefficient of Thermal Expansion—								
at 25°–100° C.	14×10^{-6}	—	$12 \cdot 3 \times 10^{-6}$	13×10^{-6}	$11 \cdot 5 \times 10^{-6}$	10×10^{-6}	11×10^{-6}	11×10^{-6}
at 25°–300° C.	15×10^{-6}	—	$14 \cdot 7 \times 10^{-6}$	—	—	—	—	—
at 25°–600° C.	16×10^{-6}	—	$15 \cdot 6 \times 10^{-6}$	—	$16 \cdot 1 \times 10^{-6}$	—	—	—
Mean Specific Heat	0·127	0·13	0·13	0·13	0·109	0·092	0·094	0·11
Thermal Conductivity, c.g.s. units	0·06	0·06	0·06	0·14	0·04	0·03	0·03	0·05
Magnetic Transformation	43°–60° C.	—	– 57° C.	360° C.	– 40° C.	—	—	—
Electrical Resistivity microhms/sq. cm./cm.	42·5	—	—	11·0	—	142	135	115
Temperature Coefficient of Resistivity per ° C.	0·00198	—	—	0·0043 0·0050	—	—	—	—
NOMINAL CHEMICAL COMPOSITION								
Nickel %	67·0	66·5	66·0	97·0	78·0	63·0	56·0	85·0
Copper %	28·5	28·0	27·5	—	—	—	—	3·0
Iron %	1·5	1·5	1·5	0·5	6·0	5·0	5·0	—
Manganese %	1·0	1·0	1·0	1·0	0·6	0·75	0·75	—
Silicon %	1·8	2·75	3·75	1·3	1·75	0·75	0·75	10·0
Chromium %	—	—	—	—	13·5	—	15·0	—
Molybdenum %	—	—	—	—	—	30·0	17·0	—
Tungsten %	—	—	—	—	—	—	5·0	—

presence of these elements is the improvement in mechanical properties. Thus pure nickel in the sand cast condition would be relatively soft and possess a yield point of only 4–5 tons/sq. in. The presence of approximately 1% of both manganese and silicon, however, results in a substantial increase in this property with little reduction in toughness (see Table II).

The alloy Monel is obtained directly by smelting a complex cupro-nickel ore. This operation is carried out under controlled conditions to yield an alloy of the composition shown in Table II, with the exception of the manganese and silicon contents. These elements are added in the foundry during remelting in order to facilitate the production of high quality, non-porous castings.

Nickel and copper alloy to form a complete series of solid solutions and consequently Monel, as smelted, consists of a single solid solution only. The addition of silicon results in the formation of a second phase, based on nickel silicide, which is precipitated as a dispersion of fine particles throughout the solid solution matrix. The quantity and form of this second phase, which is largely controlled by the silicon content, determines the mechanical properties and hardness of the alloy. Consequently, by varying the silicon content it is possible to produce a series of alloys possessing a wide range of mechanical properties.

Fig. 1, which has been constructed from average results obtained on sand-cast test bars, illustrates this effect of silicon additions. However, rate of cooling also affects the quantity and distribution of the nickel silicide phase. Consequently, mechanical properties are to some extent dependent on the mass of the casting and in practice, some deviation from these curves is to be expected.

In order to take full advantage of the effect of varying silicon content, three standard grades of Monel are now available. The ordinary grade contains only 1·8% silicon which has little effect on the mechanical properties. The presence of this small amount of silicon is, however, desirable in order to ensure the necessary fluidity and castability. The grade containing 2·75% silicon possesses a higher tensile strength, is appreciably harder and more wear resistant whilst possessing a good resistance to impact and shock loading. Increasing the silicon content to 3·75% results in the formation of a very hard alloy, which is extremely resistant to wear and erosion. However, these useful properties are only obtained at the expense of ductility and toughness, as reference to Table II will show, and, consequently,

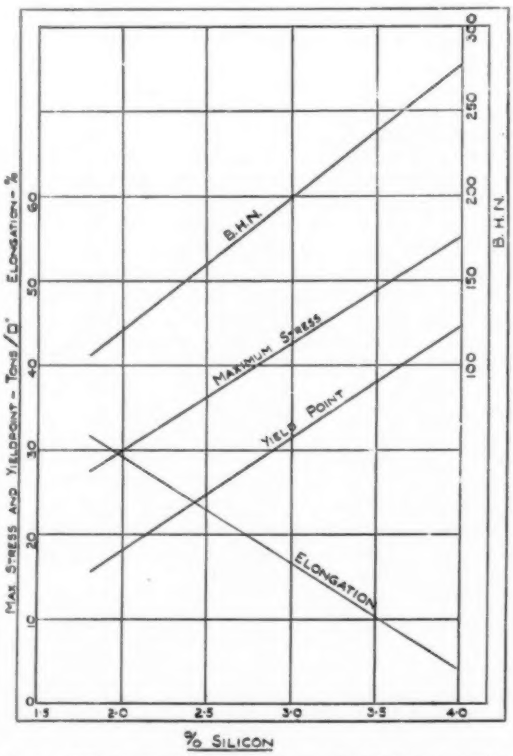


Fig. 1.—Effect of silicon on the mechanical properties of Monel.

castings in this alloy should not be subject to shock or bending stresses unless well supported.

Monel, in common with most nickel alloys, contains a small amount of carbon which promotes fluidity and facilitates the production of sound castings. Providing it remains in solid solution, carbon does not have a serious effect on the mechanical properties or corrosion resistance. However, if it is precipitated as graphite a serious reduction in tensile strength and toughness may result. The presence of silicon reduces the solid solubility of carbon in Monel and hence the maximum desirable carbon content is controlled by the silicon content of the alloy. Thus a carbon content as high as 0·35% may be tolerated in the 1·8% silicon alloy, but in the case of the 3·75% silicon alloy, more than 0·15% of this element may cause undue brittleness and 0·05–0·10% is to be preferred.

The composition of Inconel is substantially the same as the original alloy referred to above, although it is now the practice to incorporate small percentages of other elements, in particular silicon and manganese, with the object of ensuring good casting properties resulting in sound homogenous castings possessing good mechanical properties.

Constitutionally, Inconel consists of a ternary solid solution of nickel, chromium and iron. However, such alloys invariably contain a small percentage of carbon which occurs as a separate phase based on chromium carbide. Thus, carbon has the effect of extracting chromium from the solid solution and, consequently, for alloys of constant chromium content, the lower the carbon the greater will be the concentration of chromium in solid solution, and hence, the better the resistance to corrosion and oxidation.

The mechanical properties of Inconel are also dependent on the quantity and form of the carbide phase, and, as in the case of steel, the strength and hardness increase with carbon content, whilst the ductility and toughness decrease. For optimum all-round performance, the carbon content of Inconel should be in the region of 0·1%, in which case the alloy possesses an excellent combination of strength, toughness and corrosion resistance.

The other three alloys dealt with in this article are, in many respects, similar to three of the alloys investigated by McCurdy and referred to above. Langalloy 4R consists of a saturated solid solution of molybdenum in nickel, a type of structure which possesses maximum corrosion resistance to hydrochloric acid. This alloy is susceptible to precipitation-hardening and may, therefore, be heat-treated to increase the hardness and improve the resistance to wear and abrasion.

Langalloy 5R has been developed from the preceding alloy by replacing part of the molybdenum with chromium. By this means the reaction of the alloy to a corrosive environment is considerably modified. For example, whilst Langalloy 4R is particularly resistant to reducing acids such as hydrochloric, Langalloy 5R possesses an extremely high resistance to strongly oxidising substances. For specific duties, Langalloy 5R may also be hardened to increase resistance to abrasion and wear.

Langalloy 6R is an entirely different type of alloy, the only major constituents being nickel and silicon. This alloy consists of an α solid solution of silicon in nickel together with a substantial proportion of a eutectic consisting of the α solid solution and a nickel silicide phase. The large quantity of the latter phase promotes a high degree of hardness, with the result that the alloy is also somewhat brittle and difficult to machine. It is, nevertheless, one of the most suitable materials for handling sulphuric acid under certain conditions of temperature and concentration.

HEAT RESISTANCE

The majority of nickel alloys employed in the production of sand-castings possess the ability to withstand attack by hot oxidising atmospheres and many other gases. However, widely varying conditions are encountered in service at elevated temperatures, and consequently, it is impossible to lay down hard and fast rules for the selection of the most suitable alloy.

When heated in oxidising atmospheres nickel forms a superficial, tenacious scale which serves to protect it from serious oxidation at temperatures up to 750° C. It is also resistant to superheated steam at temperatures normally encountered but it is not recommended for use in sulphur-bearing atmospheres above about 530° C. since, under these conditions, it is subject to general and intergranular corrosion.

The behaviour of Monel in hot gases is very similar to that of nickel, although in some cases—e.g., oxidising atmospheres—the maximum safe temperature may be 50°–100° C. lower.

Inconel is resistant to progressive atmospheric oxidation at temperatures as high as 1,000° C. It is not readily attacked by oxidising sulphurous-atmospheres at temperatures below 800° C. although in atmospheres containing sulphur in the reduced form the maximum safe operating temperature may be somewhat lower; approximately 550° C. Inconel is also extremely resistant to high-temperature steam and is particularly useful in this respect at temperature in excess of 450° C.

Resistance to attack by hot gases is also a feature of the Langalloy series of alloys. Langalloy 5R is the most satisfactory in this respect, being highly resistant to oxidation and scaling in a wide variety of oxidising and reducing atmospheres at temperatures as high as 1,000° C.

There is, of course, another aspect of heat-resistance and that is the ability to retain a satisfactory strength at the service temperature. Nickel alloys are well known for their excellent behaviour in this respect. Of the alloys under consideration, Inconel and Langalloys 4R and 5R retain their strength to a very satisfactory degree at temperatures as high as 800° C. and even at 1,000° C., they possess tensile strengths satisfactory for many applications. Monel and nickel are not nearly so satisfactory in this respect, but even these alloys show only a slight reduction in strength providing operating temperatures do not greatly exceed 500° C.

CORROSION RESISTANCE

From the electro-chemical point of view nickel and nickel alloys are relatively noble and consequently they do not readily evolve hydrogen from solutions in the absence of depolarising agents. They are, therefore, most resistant to corrosion when conditions are reducing, whilst the presence of oxygen or oxidising agents, which facilitate the liberation of hydrogen, usually tend to promote attack. Inconel and Langalloy 5R however, are exceptional in this respect, for although they possess a high resistance to corrosion by many solutions which are reducing in nature, they are also highly resistant to a

	Monel	Nickel	Inconel	Langalloy 4R	Langalloy 5R	Langalloy 6R
Acetic Acid	■		■	■	■	■
Alums	■	■	■	■	■	■
Ammoniacal Liquors			■	■	■	■
Bleach Liquor					■	
Brines	■	■	■	■	■	■
Bromine (Wet)...	□	□		□	■	□
Calcium Chloride	■	■	■	■	■	■
Calcium Hypochlorite					■	
Carbolic Acid	■	■	■	□	□	□
Chlorine (Wet)					■	
Chromic Acid					■	
Fatty Acids	■	■	■	□	■	□
Ferric Chloride...					■	
Fruit Juices	■	■	■	□	■	□
Hydrochloric Acid (Cold) ...				■	■	
Hydrochloric Acid (Hot) ...				■		
Hydrogen Sulphide (Wet) ...		■	■	■	■	■
Inks	□	□	■	□	■	□
Lactic Acid	■	■	■	□	■	□

	Monel	Nickel	Inconel	Langalloy 4R	Langalloy 5R	Langalloy 6R
Milk	■	■	■	□	□	□
Nitrating Acids...			□	□		□
Nitric Acid (Cold)			■	□	■	□
Nitric Acid (Hot)						
Phosphoric Acid (Cold)... ...	■	■	■	■	■	■
Phosphoric Acid (Hot)	■			■	■	■
Potassium Permanganate... ...			■		■	■
Seawater	■	■	■	■	■	■
Silver Bromide...			■	□	■	□
Silver Nitrate			■	□	■	□
Sodium Carbonate	■	■	■	■	■	■
Sodium Hydroxide	■	■	■	□	□	□
Sodium Hypochlorite					■	
Sodium Phosphate	■	■	□	□	■	■
Sodium Thiosulphate	■	■	■	□	□	□
Sulphur Dioxide (Wet)... ...				□	■	■
Sulphuric Acid (Cold)	■	□	■	■	■	■
Sulphuric Acid (Hot)				■		■
Sulphuric Anhydride	□	□	□	□	□	■

■—Very good. ■—Very good in general but under certain conditions of temperature, concentration, etc., may not be entirely satisfactory. —Corrosion rates may vary considerably depending on conditions (temperature, concentration, etc.) Use with caution. □—In a few cases blank squares indicate lack of information but in general they imply that the use of the alloy in question would not be necessary.

Fig. 2.—Corrosion Resistance Chart.

wide variety of strongly oxidising media ; a valuable characteristic which is due to the presence of a substantial percentage of chromium.

The range of corrosive media in which these alloys can operate successfully for prolonged periods is far too extensive to discuss in detail. The corrosion chart reproduced in Fig. 2 serves to indicate, in general terms, the suitability of each alloy for use in contact with a selected list of corrosive agents. It must be stressed that the information obtained from this chart should not necessarily be regarded as a definite recommendation, since corrosion rates may be subject to considerable variation dependent on the prevailing conditions—e.g., concentration, temperature, pressure, velocity, degree of aeration and the purity of the corrosives encountered. In spite of this limitation, however, it is felt that the corrosion chart can be of valuable assistance particularly if considered in conjunction with the following more detailed information.

Mineral Acids

Sulphuric Acid.—The extent to which nickel alloys are corroded by the pure mineral acids is, in many cases, dependent on the degree of aeration of the solution.

The effect of dissolved air on the corrosion of Monel by sulphuric acid is illustrated by the graph shown in Fig. 3.[3] It will be observed that this alloy is only slightly attacked by the air free acid when the concentration is less than 85%, whilst the presence of dissolved air results in a substantial increase in the rate of corrosion. Oxygen plays an even more important role in the corrosion of Monel by hot sulphuric acid. In air saturated acid the corrosion rate increases rapidly with temperature up to approximately 80° C., but above this temperature the reduced solubility of oxygen results in a progressive reduction in the rate of corrosion up to the boiling point. Corrosion in the air free acid, on the other hand, remains quite low over the whole temperature range, as reference to Fig. 4 will show.[3]

Although nickel and Inconel possess a fair resistance to corrosion by sulphuric acid, they are, in general, inferior to Monel and consequently are seldom used for such applications.

Langalloys 4R, 5R, and 6R, are extremely resistant to attack by all concentrations of sulphuric acid at room temperature but, as in the case of Monel, the presence of dissolved oxygen tends to promote attack. The rate at

3 " Monel in Sulphuric Acid," Publication of The International Nickel Co. Inc.

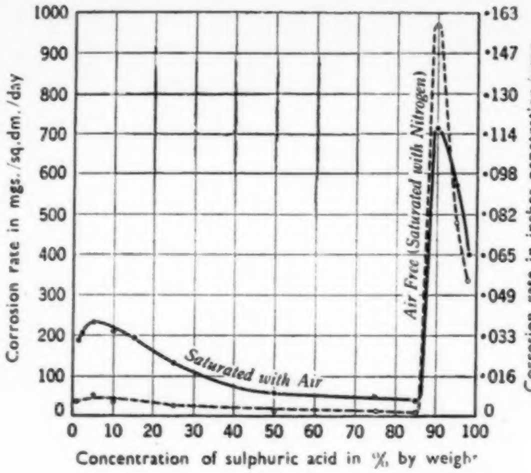


Fig. 3.—Corrosion of Monel in sulphuric acid, at a temperature of 30° C. and velocity of 17 ft./min.

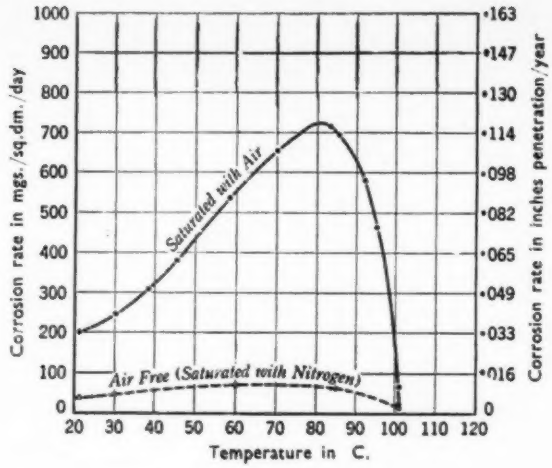


Fig. 4.—The effect of temperature on the corrosion of Monel in 5–6% sulphuric acid at a velocity of 15·5–16·5 ft./min.

which Langalloys 4R and 5R are corroded in the higher concentrations of air free and aerated sulphuric acid are shown in Fig. 5, from which it will be seen that the presence of dissolved oxygen causes an appreciable increase in the rate of corrosion of Langalloy 4R, whilst Langalloy 5R is corroded at the extremely low rate of less than 0·0001 in./year, even in the aerated solution.

At elevated temperatures appreciably higher corrosion rates are, of course, to be expected. Langalloy 5R retains a high degree of corrosion resistance at temperatures up to 80° C. providing the concentration of acid does not greatly exceed 20%, but apart from this somewhat restricted range, Langalloy 4R is the most generally useful alloy for service in hot sulphuric acid. This alloy is particularly resistant to attack by all concentrations at temperatures up to 150° C. It is more rapidly attacked by boiling solutions containing in the region of 70–90% sulphuric acid but over this range of concentration Langalloy 6R proves to be the most resistant alloy.

Thus Langalloys 4R, 5R, and 6R all prove useful for handling sulphuric acid and Fig. 6 has been compiled in an endeavour to facilitate the selection of the most resistant alloy for all ranges of concentration and temperature.

Hydrochloric Acid.—This acid is considered to be the most corrosive of all the mineral acids and few metallic

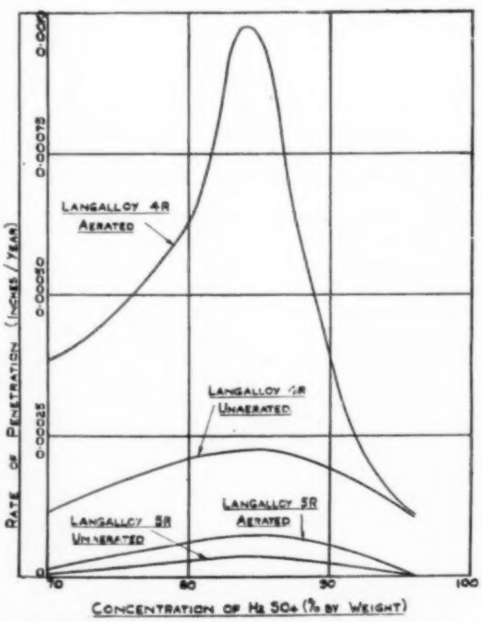


Fig. 5.—Corrosion of Langalloys 4R and 5R in aerated and unaerated sulphuric acid.

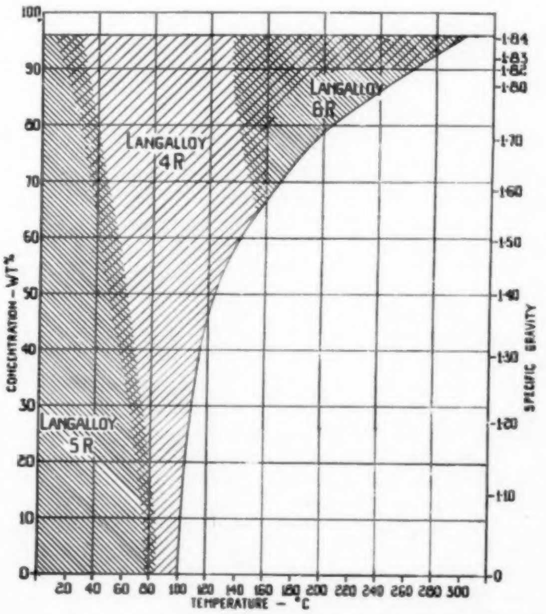


Fig. 6.—Diagram indicating the most suitable Langalloy for resistance to sulphuric acid at any temperature or concentration.

materials have the ability to withstand attack by the higher concentrations at elevated temperatures.

Monel, nickel and Inconel possess a fair resistance to corrosion by the air free acid providing the concentration does not greatly exceed 10% by weight. However, concentration and degree of aeration have a very pronounced effect on the rate of corrosion, this being illustrated, in the case of Monel, by the data presented in Fig. 7. These alloys are much more rapidly attacked at elevated temperatures, and although they may be employed occasionally for handling hot solutions containing less than 2–3% acid, they are generally considered to be unsatisfactory for applications involving contact with hot hydrochloric acid.

Fig. 7 also contains the results of corrosion tests on Langalloy 4R in aerated and unaerated hydrochloric acid. It will be observed that this alloy possesses an excellent resistance to corrosion over the whole range of concentrations and that, compared with Monel, it is only slightly affected by the degree of aeration of the solution. It is, of course, more rapidly attacked by the hot acid, but, even in the presence of an abundant supply of oxygen, corrosion rates seldom exceed 0·04 in./year, even at temperatures as high as the boiling point. Langalloy 4R may, therefore, be regarded as the most satisfactory type of commercially available alloy for handling hydrochloric acid over the whole range of temperature and concentration.

Langalloys 5R and 6R are also usefully resistant to attack by hydrochloric acid at room temperature. The former alloy is, in fact, slightly superior to Langalloy 4R for handling cold solutions containing less than 5% of this acid.

Phosphoric Acid.—Pure phosphoric acid solutions, at temperatures in the region of 30° C. do not readily corrode Monel, nickel or Inconel. Monel also possesses a useful resistance to all concentrations at temperature up to approximately 100° C., but nickel and Inconel may be rapidly attacked by hot solutions, particularly if the concentration of acid is high.

Langalloys 4R, 5R, and 6R all possess an excellent resistance to corrosion by this acid. In cold solutions Langalloy 5R is particularly resistant, corrosion rates on laboratory test being invariably below 0·0001 in./year. In the hot acid, on the other hand, Langalloy 4R is generally the most resistant, its superiority being particularly marked at temperatures at or near the boiling point.

Miscellaneous Mineral Acids.—Nickel alloys are being successfully employed in handling the majority of other less common mineral acids. Monel, nickel and Inconel are not seriously attacked by very dilute solutions of sulphurous acid—e.g., as used in the food industry, although there is a tendency for them to tarnish under such conditions. The more concentrated solutions of this acid are very corrosive and may attack these alloys rapidly. Langalloy 5R, however, is extremely resistant to all concentrations, including wet sulphur dioxide gas. Hydrofluoric acid is not particularly corrosive to nickel alloys and of the alloys under consideration Monel is usually regarded as the most satisfactory. Typical results of corrosion tests on this alloy in hydrofluoric acid under various conditions are shown in Table III.[4] The strongly oxidising acids are the most corrosive to nickel alloys, but, even so, Langalloy 5R proves to be most satisfactory for handling such acids and acid mixtures as nitric, chromic, nitro-sulphuric, chromic-sulphuric, etc., over wide ranges of concentration and temperature.

TABLE III.—CORROSION TESTS ON MONEL IN HYDROFLUORIC ACID.

Acid Concentration %	Temperature ° C.	Duration of Test Days	Corrosion Rate: Mgs./sq. dm./day	Corrosion Rate: Inches/year	
25	30	1	230·0	0·0380	Agitated with air at 300 cc./min.
25	80	1	67·0	0·0110	
50	30	1	48·7	0·0079	
50	80	1	241·0	0·0400	
25	30	6	1·0	0·0002	Agitated with nitrogen at 100 cc./min.
25	80	6	14·5	0·0024	
50	30	6	0·4	0·00006	
50	80	6	3·6	0·0006	

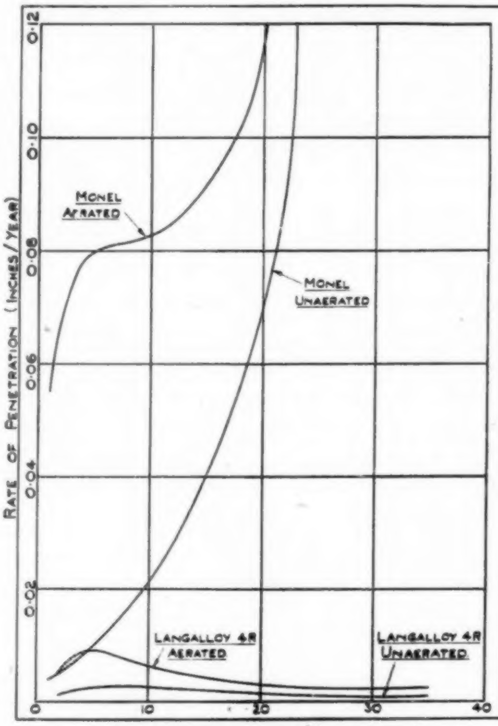


Fig. 7.—Corrosion of Monel and Langalloy 4R in aerated and unaerated hydrochloric acid.

Effect of Impurities.—In considering the relative merits of metals and alloys for applications demanding a low rate of corrosion in mineral acids, it is of the utmost importance that careful attention be paid to the possible effects of any impurities which may be present in the solutions. Of the impurities commonly encountered the oxidising metal salts are the most serious. These compounds, which act as depolarising agents, tend to promote attack and corrosion rates may be increased to such an extent that otherwise useful alloys may be rendered quite inadequate. This is illustrated by the data in Table IV which demonstrates the effect of ferric sulphate on the corrosion of Monel by sulphuric acid.[3]

In the presence of such oxidising salts the chromium-containing alloys invariably prove the most satisfactory. The results shown in Table V indicate that Inconel is

4 Morton, B. B. "Corrosion in Petroleum Refineries," *The Petroleum Engineer*, May, 1944.

TABLE IV.—CORROSION OF MONEL BY SULPHURIC ACID CONTAINING FERRIC SULPHATE.

% H_2SO_4	% Fe*	Corrosion Rate	
		Mgs./sq.dm./day	Inches/year
2·02	Nil	170	0·026
2·44	1·0	6,990	1·055
1·60	Nil	140	0·021
1·66	0·05	1,215	0·180
0·532	Nil	115	0·017
0·604	0·05	1,493	0·228
0·710	0·10	2,600	0·396
0·0635	Nil	76	0·011
0·0650	0·005	243	0·037
0·0857	0·010	421	0·064

* Added as Ferric Sulphate.

TABLE V.—CORROSION TESTS IN SULPHURIC ACID CONTAINING COPPER SULPHATE.

Test specimens exposed to a spray of 10% Sulphuric acid containing 2% copper sulphate.

Temperature .. .. 32° C.
Duration of Test .. .. 176 hours.

Alloy	Corrosion Rate	
	Mgs./sq.dm./day	Inches/year
Monel	552	0·090
Nickel	528	0·086
Inconel	0·42	0·00007

far superior to Monel and nickel for handling 10% sulphuric acid solution contaminated with copper sulphate.[3] This effect is further demonstrated by the results of corrosion tests in pure and commercial hydrochloric acid quoted in Table VI. It will be noted that Monel is corroded much more rapidly by the commercial acid due to the presence of oxidising ferric salts whilst Inconel is attacked at approximately the same rate in both solutions.

TABLE VI.—CORROSION TESTS IN PURE AND COMMERCIAL HYDROCHLORIC ACID AT 30° C.

Alloy	10% HCl (Pure)		10% HCl (Commercial)	
	Mgs./sq. dm./day	Inches/Year	Mgs./sq. dm./day	Inches/Year
Monel	69	0·010	810	0·144
Inconel	34	0·005	35	0·005

TABLE VII.—CORROSION TESTS IN AQUEOUS SOLUTION CONTAINING 1% $FeCl_3$ and 1% HCl at 30° C.

Alloy	Corrosion Rate	
	Mgs./sq.dm./day	Inches/year
Langalloy 5R	12	0·0018
Inconel	164	0·0252
Langalloy 4R	274	0·0420
Monel	523	0·0792
Gunmetal	1,252	0·1920

However, Inconel, though generally superior to the chromium-free alloys in resisting attack by such oxidising acidic solutions, is not nearly so satisfactory as Langalloy 5R in this respect. This alloy is highly resistant to all manner of strongly oxidising solutions and is particularly satisfactory for handling acidic solutions containing substantial quantities of ferric, cupric, and other readily reducible salts. Corrosion tests in acidic ferric chloride and vanadium sulphate solutions are shown in Tables VII and VIII from which it will be seen that Langalloy 5R possesses an outstanding resistance to attack by such severely corrosive solutions.

Commercial phosphoric acid produced from phosphate-rock also contains oxidising impurities such as ferric salts and fluorine. It is, therefore, extremely corrosive to the majority of metallic materials, but, in this case, also, Langalloy 5R has proved to be highly resistant and most useful for the construction of items of plant which were previously susceptible to severe corrosion.

Organic Acids

Cast nickel alloys are little affected by organic acids, but when the highest possible degree of corrosion resistance is required the chromium containing alloys—i.e., Inconel and Langalloy 5R, should be selected. The latter alloy is practically unaffected by acetic acid in all concentrations at temperatures up to the boiling point, whilst Inconel suffers little to no corrosion in many solutions containing organic acids and compounds such as fruit juices, sauces, milk and fatty acids. It is, therefore, ideally suited for many applications involving contact with foodstuffs when excellent corrosion resistance is of vital importance in order that metallic contamination of the product may be avoided.

Alkalies

All these nickel alloys are highly resistant to solutions of caustic alkalies. Under the most corrosive conditions and when absence of metallic contamination is of the greatest importance, nickel is to be preferred. This material is, in fact, second only to silver in resisting corrosion by high concentrations of caustic soda at temperatures as high as 400°–500° C. encountered during the concentration process. In such a process, corrosion rates vary enormously depending on the concentration, temperature, degree of agitation, etc., but even in anhydrous NaOH at 400° C. nickel was corroded at the rate of only 0·009 in./year on laboratory test.[5]

These alloys are not attacked by dry ammonia, but the rate at which nickel and Monel are corroded by the aqueous solution increases rapidly when the concentration exceeds 1 and 3%, respectively. However, Inconel and the alloys of the Langalloy series resist attack by this solution over wide ranges of concentration and temperature.

TABLE VIII.—CORROSION TESTS IN AQUEOUS SOLUTION CONTAINING 5% VANADIUM (AS SULPHATE) AND 9% SULPHURIC ACID AT 70° C.

Alloy	Corrosion Rate	
	Mgs./sq.dm./day	Inches/year
Langalloy 5R	19·2	0·003
Inconel	3208·0	0·480
Monel	3659·0	0·552

Salt Solutions

Non-oxidising salt solutions are only slightly corrosive to these nickel alloys and, in general, Monel or nickel are perfectly satisfactory. In a few cases these two alloys have exhibited a tendency to slight pitting and, if it is imperative that this form of attack should be completely eliminated, Langalloy 5R should be used, tests on this alloy in brine and sea-water having shown complete freedom from both general and localised corrosion.

Non-oxidising acid salts such as aluminium sulphate, ammonium sulphate, zinc chloride, etc., are, in general, somewhat more corrosive than the neutral or alkaline salts. Nevertheless, Monel, nickel, and Inconel are perfectly satisfactory for handling the aqueous solutions under the conditions normally encountered, but for applications demanding an exceptionally low rate of

5 "The Resistance of Nickel and its Alloys to Corrosion by Caustic Alkalies," Publication of The International Nickel Co., Inc.

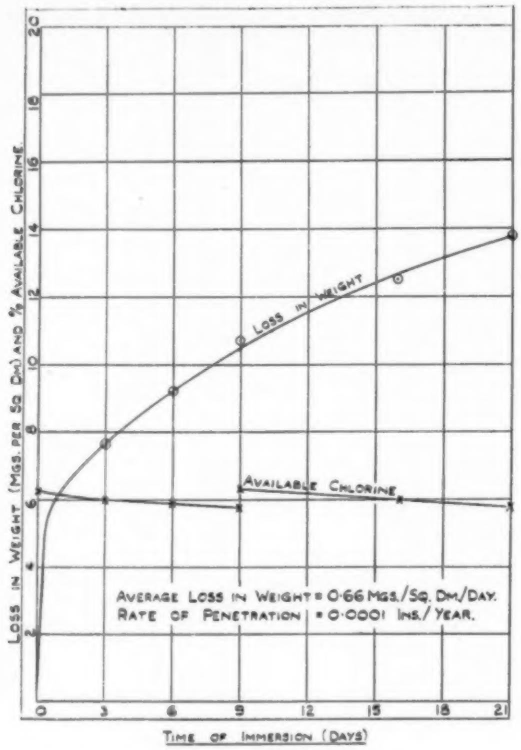


Fig. 8.—Corrosion of Langalloy 5R in sodium hypochlorite.

corrosion under the most arduous conditions, Langalloy 4R or 5R are to be recommended.

The most corrosive types of salt solutions are those which behave as strong oxidising agents. Acidic oxidising salts which comprise ferric, cupric and other readily reducible metal salts are extremely corrosive to the majority of metals and alloys. However, Langalloy 5R resists attack by such solutions in a very satisfactory manner, as indicated by the data in Tables VII and VIII to which reference has already been made, but even this alloy may be rapidly attacked by very hot, strong solutions of the more corrosive salts.

The hypochlorites are the most corrosive of the oxidising alkaline salts. These solutions attack nickel, Monel and Inconel rapidly unless the available chlorine content is quite low—i.e., less than 3 gm./litre. Langalloy 5R, on the other hand, is highly resistant to all concentrations of these solutions providing room temperature is not greatly exceeded.

The excellent resistance of Langalloy 5R to corrosion by sodium hypochlorite solution has been demonstrated by immersion tests in a solution containing approximately 6% available chlorine. The test was continued for 21 days, the loss in weight of the specimen and available chlorine content of the solution being determined after 1, 3, 6, 9, 16, and 21 days immersion. The results are presented in Fig. 8 from which it will be seen that, although the available chlorine content was maintained at approximately 6% (by replenishing the solution after the ninth day) the total loss in weight was only 13·8 mgs./sq. dm. or 0·66 mgs./sq. dm./day, which is equivalent to 0·0001 in. penetration per year. At the end of this 21 days' test the specimen was completely unaffected to the naked eye.

Gases

Dry gases attack nickel alloys only at elevated temperatures, and as this form of corrosion has been referred to in the section on heat-resistance, further discussion is unnecessary.

Certain gases are very corrosive when moisture is present. Thus Monel and nickel are rapidly attacked by chlorine, bromine, sulphur dioxide and ammonia in the presence of moisture. However, Inconel and the alloys of the Langalloy type are highly resistant to wet ammonia, whilst Langalloy 5R is to be recommended for use in contact with the more corrosive moist gases such as chlorine, sulphur dioxide, sulphur trioxide and many others.

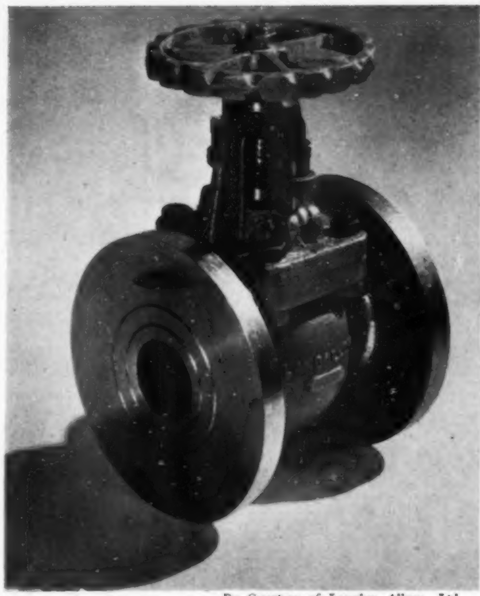
INDUSTRIAL APPLICATIONS OF NICKEL ALLOY CASTINGS

Until the end of the 1914–1918 War, the chemical engineer had a very limited selection of materials from which to build equipment for the handling of corrosive substances. Such equipment was constructed largely from wood, stoneware, lead or cast iron, which, though probably possessing a fair resistance to attack by the corrosives handled, were, nevertheless, quite inefficient for many applications, due to their poor mechanical properties. Since that time a vast amount of research has been directed towards the development of strong, tough, corrosion-resistant alloys with the result that to-day, alloys possessing excellent combinations of mechanical properties and corrosion-resistance, are available for practically all types of corrosion-resistant service. By no means the least important of these is the range of cast nickel alloys considered in this article.

It is, of course, impossible to deal exhaustively with the multitude of uses which these alloys find in almost every branch of industry, but it is hoped that the following will serve to indicate some of the more typical applications for which castings in these alloys are ideally suited.

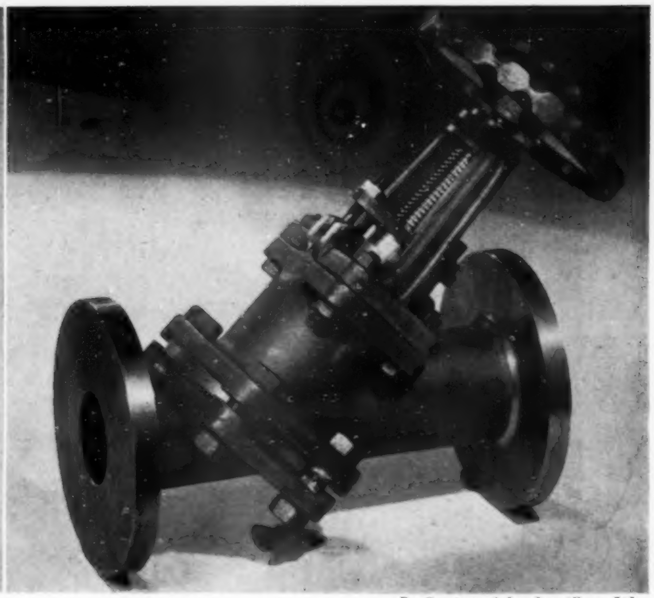
Food Industry.—In the food industry, it is vitally important to reduce corrosion of processing equipment to a minimum in order to prevent contamination of the product by metallic salts produced in the corrosion process. The effect of such contamination on the product will, of course, depend on the contaminant. Thus, it has been suggested that as little as 0·8 parts per million of copper will develop off flavours in certain dairy products. More than 16 parts per million of copper will affect the colour and flavour of tomato juice ; iron and tin affect the colour and brilliance of certain wines, whilst these metals are also most active in producing turbidity in beer and spirits.

The majority of investigations which have been carried out on the effect of metallic contamination on foodstuffs have shown that nickel is not nearly so deleterious as many other common metals. Thus the high resistance of nickel alloys to corrosion by most of the substances used in the food industry, coupled with the fact that nickel contamination is not very serious if a small amount of corrosion does occur, has resulted in their large scale application in food processing equipment.



By Courtesy of Langley Alloys, Ltd.

Fig. 9.—Langalloy 4R globe valve.



By Courtesy of Langley Alloys, Ltd.

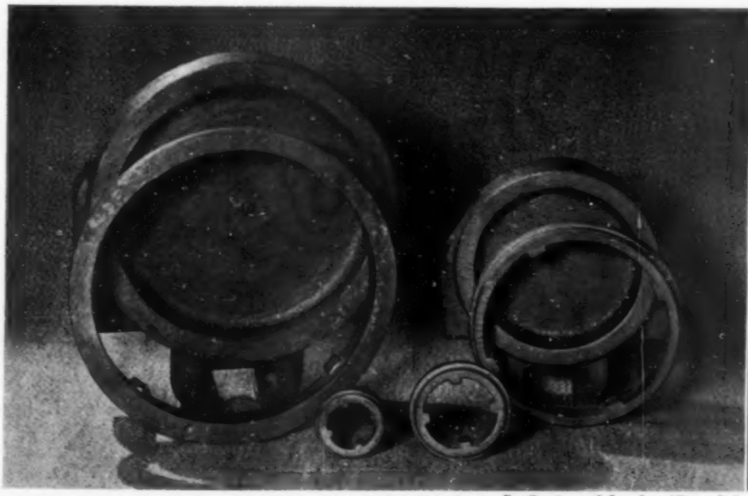
Fig. 10.—Langalloy 5R Y-valve.

Monel, nickel, and Inconel castings in the form of pump and valve components, pipe fittings, etc., are employed in the construction of equipment handling milk and milk products. Inconel is the most versatile alloy in this respect, being the more resistant to hot aerated milk, but Monel and nickel also give very good service in many applications of this type.

These three alloys are also well known for their resistance to corrosion by fruit and vegetable juices and castings are employed in pulping machines, pumps, pipe lines, bottle filling machines and metering devices. In this case also, Inconel is, in general, the most satisfactory, being somewhat more resistant to corrosion by hot or boiling juices, sauces, etc., than Monel and nickel.

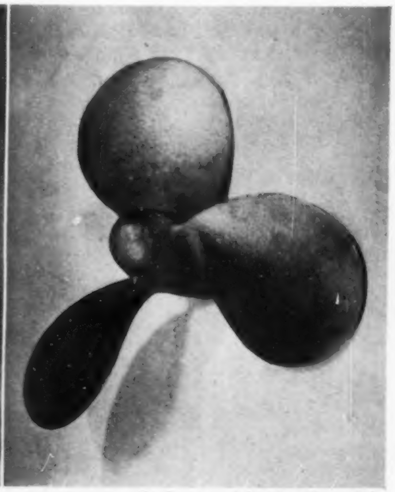
Other applications for nickel alloy castings in the food industry include components for mixing, slicing and cutting machines, pipe fittings and flanges for heating coils and items for the fabrication of heat exchangers, stills, etc., as used in fatty acid distillation.

The preservation of purity of the product is a first essential in the food industry, and whilst much can be achieved by the use of nickel alloys in processing equipment, it is also of primary importance that the latter should be maintained in a perfect state of cleanliness. In order to achieve this effect rapidly and economically, food manufacturers frequently resort to the use of highly corrosive or abrasive detergents. This introduces another aspect of the selection of materials, since they must be resistant to wear and corrosion by such substances. From this point of view also, these nickel alloys have



By Courtesy of Langley Alloys, Ltd.

Fig. 11.—Valve rings and wedges in Langalloy 4R



By Courtesy of Langley Alloys, Ltd

Fig. 12.—Propeller-type mixer in Monel

By Courtesy of Langley Alloys, Ltd.

← **Fig. 13.—Agitator constructed entirely from Langalloy 4R castings.**

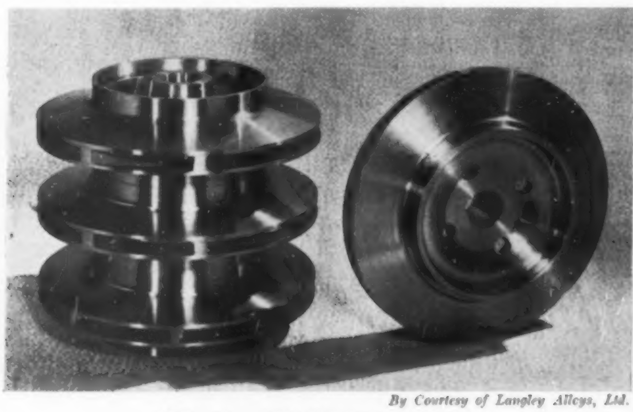
By Courtesy of Langley Alloys, Ltd.

Fig. 16.—Monel centrifuge body.

proved highly satisfactory, since they possess an excellent resistance to corrosion by such popular detergents as hot caustic solution and surfaces are not readily damaged by abrasive cleansing compounds.

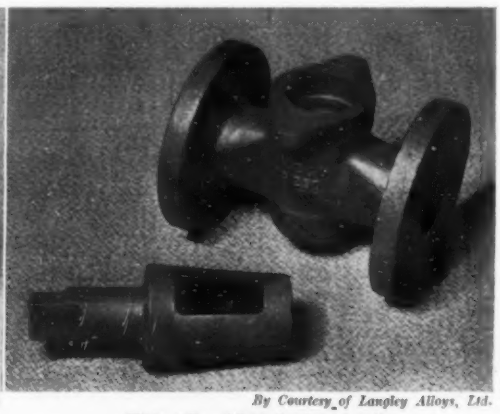
Chemical and Petroleum Industries.—Nickel alloy castings are being used in ever increasing quantities by the chemical and petroleum industries. In the form of pump bodies, impellers, pipe fittings such as tees, elbows, etc., valves and valve trim, Langalloys 4R, 5R, and 6R are giving excellent service in handling strong mineral acids and acidic solutions, strongly oxidising solutions and many organic substances. Figs. 9 and 10, for example, illustrate two types of valves which are available in Langalloys 4R and 5R, whilst Fig. 11 shows a group of valve trim components for use in gate valves as employed in oil refineries for handling hot sulphuric acid. Other typical uses include thermometer pockets, immersion heater tubes, plug cocks, scraper knives, and many types of mixer and agitator components. Fig. 12 is a typical example of a propeller-type mixer, and Fig. 13 is an agitator constructed entirely from Langalloy 4R castings for use in a mixture containing up to 35% hydrochloric acid.

There are, of course, many applications in these industries which do not demand the exceptionally high corrosion resistance of the Langalloy series and Monel, nickel, and Inconel find many applications in such environments. Thus Monel is extensively used for handling sulphuric acid and many salt solutions. This alloy is particularly useful for the construction of pumps, valves and plug cocks due to the fact that it is available in three grades of different hardness. This enables one to select the alloy possessing the most satisfactory properties for each component of the valve, pump, etc., whilst retaining the same high degree of corrosion resistance throughout and without creating a tendency for galvanic corrosion to occur as might be the case if dissimilar alloys were used. Fig. 14 shows a typical group of Monel pump impeller castings and Fig. 15 a plug cock in normal Monel, the plug for which is



By Courtesy of Langley Alloys, Ltd.

Fig. 14.—Monel pump impellers.



By Courtesy of Langley Alloys, Ltd.

Fig. 15.—Monel plug cock.

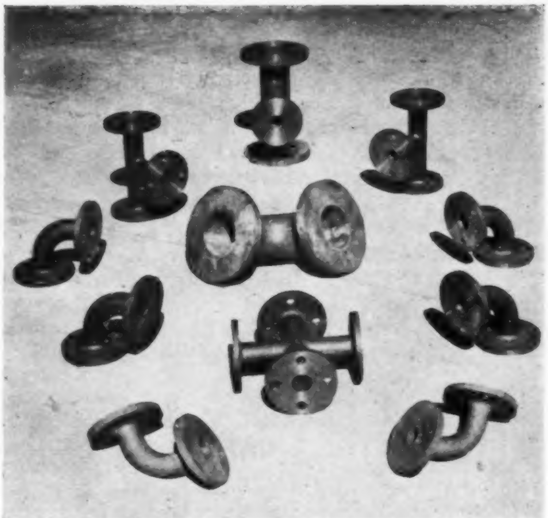


Fig. 17.—Group of Inconel pipe fittings.

preferably produced in the 2·75% silicon alloy in order to prevent scoring or seizure. Monel castings are also employed in the production of centrifuges used for separating corrosive mixtures, a typical Monel centrifuge body required for handling acid sludges being shown in Fig. 16.

The application of nickel and Inconel castings in these industries is somewhat more limited. However, large quantities of valves and pumps in the former alloy are being used for handling caustic alkalies and other alkaline solutions, whilst Fig. 17 shows a group of Inconel pipe fittings, typical of a large contract recently completed for an application demanding a high degree of corrosion resistance combined with high strength and resistance to oxidation at elevated temperatures.

Metallurgical Industries.—The major applications for corrosion resisting alloys in the metallurgical industries are in plant associated with pickling. Monel is accepted as one of the most satisfactory alloys for the construction of chains, hooks, crates, etc., for use in the sulphuric acid process, for although it is normally more rapidly attacked by sulphuric acid contaminated with metallic salts, it usually receives galvanic protection from the less noble metals being pickled and very satisfactory service life is thus obtained.

Other nickel alloys are used only for certain special applications in this industry. Inconel is used to a limited extent for certain furnace parts where a high degree of oxidation resistance and good mechanical properties at elevated temperatures are essential, whilst Langalloy 5R has been employed in the construction of fans for circulating hot furnace gases at temperatures in the region of 800° C. Fig. 18 illustrates such a fan constructed entirely from Langalloy 5R castings.

Other Industries.—Nickel alloy castings are employed in many other branches of industry where severely corrosive conditions are encountered and good performance is essential. Thus, Monel, by virtue of its excellent resistance to corrosion and cavitation-erosion by sea-water, has proved to be a most satisfactory material for sea-water pump impellers and large quantities of castings, such as those illustrated in Fig. 14, are used in marine engineering.

There are many applications for Monel castings in the soap industry where they are employed in the construction of pumps for handling brine, lye and fatty acids, for agitators mixing perfumes, colours, etc., with the soap, for screw conveyers used in transferring the product, and for cutters and dies.

In the production of artificial silk and the dyeing and bleaching of textiles in general, nickel alloys may often be used to advantage since their high degree of corrosion resistance can be very valuable in preventing metallic contamination, a factor which is of vital importance in processes such as these. Monel and Langalloy 5R have been successfully used in handling certain highly corrosive dyestuffs, whilst the latter alloy has proved to be very satisfactory when used in contact with spinning baths containing sulphuric acid, sodium sulphate and sulphides, and the excellent resistance of this alloy to corrosion by hypochlorite solutions is made use of in certain bleaching processes.

The foregoing data on properties and corrosion resistance, considered in conjunction with the typical applications quoted, serves to indicate the extent to which nickel alloy castings are being satisfactorily employed in reducing corrosion of processing plant and other equipment. It is also probable that many other applications will have been suggested, but in this connection it may be necessary to issue a word of warning regarding the interpretation of the data presented. This information on corrosion resistance has been obtained from laboratory and/or plant corrosion tests considered in the light of subsequent service results. It is, therefore, reliable for the particular set of conditions existing during the tests or service trials. However, slight variations in operating conditions—e.g., degree of aeration, presence of impurities, velocity, etc., may have appreciable effect on the rate of corrosion and it is, therefore, most essential that accurate information of this type should be taken into consideration when selecting materials for corrosion resisting service.

A wealth of information on the behaviour of nickel alloys under all manner of corrosive environments is rapidly accumulating and when comprehensive data regarding operating conditions is available, it is frequently possible to select the most suitable alloy in all confidence without resorting to lengthy trials. When lack of information does not justify such a course,

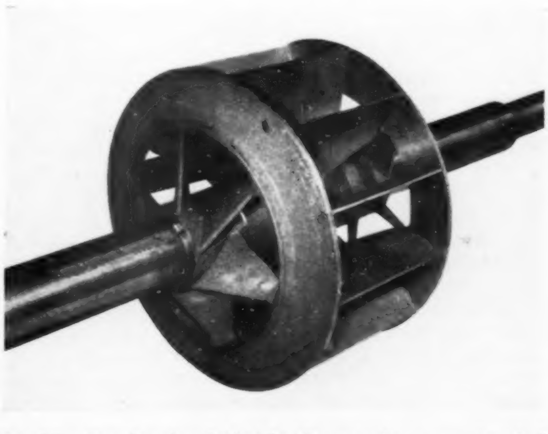


Fig. 18.—Fan for circulating hot furnace gases constructed from Langalloy 5R castings.

aboratory or, preferably, plant corrosion tests can be of enormous value providing the method of testing is technically sound and results are carefully interpreted. Unfortunately, it is not always possible to carry out tests under conditions identical with those which will eventually be encountered and whenever possible the results of corrosion tests should be subjected to corroboration by trials with actual components under operating conditions.

In considering the suitability of corrosion resisting materials, the importance of close co-operation between the manufacturer and the plant- or design-engineer cannot be over-stressed. The complete exchange of available information regarding operating conditions, properties of the materials and their behaviour on test, is most essential if successful results are to be obtained, whilst the comprehensive and reliable data so accumulated may prove to be of invaluable assistance in the continual search for improved materials to combat the most destructive agency known to engineers—corrosion.

CONCLUSION

The above review has been compiled in an endeavour to indicate the wide variety of applications in which nickel alloy castings are being successfully employed. It will, of course, be obvious that, however good the corrosion-resistance of an alloy, satisfactory service cannot be expected unless high quality castings are employed. The production of nickel alloy castings to the high standards demanded by severe service conditions is a highly specialised process necessitating strict technical control throughout. Raw materials must be carefully examined to ensure that they are of the necessary high degree of purity, melting and alloying should be adequately supervised in order to control the compositions within narrow limits, and methods of casting must be carefully designed so that the resulting castings are of good surface finish and free from internal defects.

In order to check the adequacy of the degree of control exerted, chemical analyses, often supplemented by routine corrosion tests, should be carried out on every heat and all castings submitted to a rigorous inspection. Only by rigidly adhering to such careful control can nickel alloy castings be produced to the high standard of quality which is demanded by the conditions under which they are employed.

Hot-Dip Galvanising*

A Practical Technique For Hydrochloric Acid Pickle Control

By Thomas B. Crow, Ph.D., F.R.I.C.

This concludes a Report which is concerned with an investigation carried out from the initial starting up of a hot-galvanising plant and deals with the development of a technique for the proper conduct of the pickling operations. The technique described, although primarily for the treatment of steel window frames, is generally applicable in the ferrous industry.

Iron Concentration

It has already been stated that 73 ounces of hydrogen chloride can just "deal with" 56 ounces of iron. By proportion, 150 ounces could deal with

$$\frac{56\times150}{73}=115 \text{ ounces of iron.}$$

and 318 ounces could deal with

$$\frac{56\times318}{73}=244 \text{ ounces of iron.}$$

It is not necessary to consider what particular combination of bath operating conditions (that is (a) *total* standard acid[8]; (b) *total* frequency and strength of topping up and (c) duration of pickle life, from a virgin "150" start) would correspond with the attainment of a theoretical maximum of iron concentration; suffice it to say that since we have been operating mainly with "150" acid, we should expect that the practical limit of usefulness of a bath would be reached when the iron concentration is in the region of 100 to 120 ozs. per cub. ft. This will be referred to again, but for the moment, a digression to study "iron evaluation" must be made.

Earlier in this article, the author expressed a preference for "grams per litre" or "ozs. per cub. ft." over other forms of expression of the strength of hydrochloric acid. Percentage by weight would have one value when pure water was the solvent and another when water containing iron salts was the solvent. In further elaboration of this point, hydrochloric acid of 150 ozs. per cub. ft. is 14% by weight of gas, the other 86% of the total weight being water—say 14 lbs. and 86 lbs. But if that 86 lbs. of water had 20 lbs. of iron chloride dissolved in it, the percentage of hydrogen chloride would be 14 in 120, that is under 12! Hence it is inaccurate to talk of "restoring the strength of 14%". You don't know where you are, unless you know the ferrous salt concentration and can allow for it. This argument holds equally for talk about the percentage of iron in the pickle. A 20% solution by weight of iron in water is not 20% by weight if that water also contains hydrogen chloride, which weighs something!

Attempts have been made to control pickle baths by specific gravity determinations. Here again you are in the dark unless you know the specific gravity *and* either the iron or the acid concentration. You must prepare beforehand, by means of a comprehensive range of laboratory determinations, data sheets, which will enable you to say "when the specific gravity is so and so *and* the iron concentration is so and so *and* the temperature is so and so, *then* the acid concentration will, in fact, be so and so." Likewise, for information of the iron concentration. How much better it is, then, to make a direct determination of acid strength and of iron strength by simple volumetric titration methods (see Appendix II). You can then say definitely that "I know that one cubic foot of this pickle has in it (say) 140 ounces of hydrogen chloride and 15 ounces of iron, as ferrous chloride."

*Contd. from page 302, April, 1949
8 i.e. 150 ozs. per cubic foot.

Pickle Exhaustion

So far, attention has been concentrated mainly upon the technique for maintaining the acid strength and the depth and to this end it has been advised that periodic samples be taken from the bath and assayed for their free acid content. It has also been mentioned that the pickle will become exhausted when the iron concentration reaches something over 100 ozs. per cub. ft. The advisability, therefore, of periodic iron assays is self-evident. It would thus seem that all one has to do is to take daily or periodical assays of acid and iron content, restore the acid strength as necessary and discharge the bath when the iron concentration reaches say 120 ozs. per cub. ft. Now it has already been hinted that it may not be possible, after working for some time, to maintain the acid strength unless considerable space in the bath were made available, either by artificial drag-out or by the provision of several feet of extra tank depth above the standard working level; neither of which expedients is economical. In fact, one may go further than this and state that it will most likely not be possible to maintain acid strength for very long after a fresh start with virgin 50 : 50 acid has been made ; a point will most certainly be reached early on when no further really effective acid additions can be made from the point of view of strength restoration) although one is not even " in sight of " the 100–120 iron concentration point. Exactly when this point will be reached will depend upon local working conditions ; if, for instance, a light pickling is accompanied by a considerable drag-out, there would be space for topping up. If pickling were heavy and there were little drag-out, one could not get sufficient conc. acid in (up to standard level) to keep up concentration. In an extreme (hypothetical) case where there were no drag-out—the bath would admit of no additions at all, and all that one could do then would be to stand idly by, whilst iron concentration increased and acid decreased !

A little reflection will perhaps make it clear why there must be a limit. If one were working with concentrated acid (318) one could *never* restore the strength by the addition of " 318 acid ". The reason why one can restore the strength to 150 with conc. acid is because one is adding something stronger and here it may be noted that a designedly weak pickle[9] affords more scope for restoration by means of topping up than does a stronger pickle.

There is the other side of the picture. It has been suggested to the author that where conditions permit of the continual and persistent restoration of acid strength, additions should be voluntarily stopped *anyhow* at a concentration of iron of 100 ozs. per cub. ft.

Summary

The practical procedure for pickle control may now be summarised as follows :—

(1) Maintain acid strength for as long as possible, subject to a voluntary cessation of acid additions after the iron concentration has reached 100 ozs. per cub. ft.

(2) Even though you cannot fully restore strength by topping up, do the most you can in this direction by making good the drag-out with concentrated acid.

(3) When the acid concentration is very low (say 10–20 ozs. per cub. ft. and the iron is over 100 ozs. per cub. ft.) the bath may be " flogged " to death by operating till the iron reaches 120 ozs. per cub. ft. Pickling will then be very slow[10], however, and, where a second bath is available this should by now have been brought into operation.

(4) An exhausted bath can always be used for stripping ; if necessary, by artificially dragging out a few inches and replacing with an equal volume of new conc. acid. It is not, however, usual to squander new acid on an old pickle which has been relegated to stripping duties.

Acknowledgment

The writer welcomes this opportunity of expressing his appreciation and thanks to Dr. Sydney R. Carter (Physical Chemistry Dept., University of Birmingham) for certain theoretical information, which it is hoped may form the subject of a future contribution ; to Mr. G. G. Woods (Emery Brothers, Ltd., Birmingham) for preparing Table II ; to Mr. J. F. Hinsley, for checking the manuscript and to Messrs. John Williams & Sons (Cardiff), Ltd., for permission to publish. Acknowledgment to the Chemical Rubber Publishing Company (Cleveland, Ohio) is hereby made, for data (embodied in Table I) taken from their " Handbook of Chemistry and Physics."

Appendices

I. *Surface Level.*—Fig. 4 shows a design of " depth gauge " which can be easily made and graduated to suit individual requirements. The obvious advantage of such a device is that it avoids the use of a direct measuring dip-stick which is inconvenient and liable to be inaccurate. The long base enables the device to be straddled diagonally across a corner of the bath brickwork. The sliding graduated rod is so marked that when its lower end is flush with the underside of the base, the reading indicates the actual internal overall depth of the tank to the overflow level.

The standard level can be marked out in colour, if desired. The device, being of wood should be protected from " acid dry rot " by heavily painting or coating with linseed oil, especially if it is left permanently *in situ*. The wedge enables the scale to be set at any desired level and left thus during topping-up operations. This wedge, which should be of hard wood, is provided with an " ear " at its upper end to enable it to be tapped upwards with a hammer if it should seize. The actual length of the graduated rod will be decided by convenience. The device is not primarily intended for use in the early stages of refilling an empty tank, nor need the graduated rod be *immersed* in the pickle itself.

II. *Sampling and Assaying.*—Fig. 5 illustrates a convenient form of sampling apparatus. Its construction is self-explanatory, but one or two refinements may be mentioned. The underside of the retort stand base has been heavily weighted and rubber covered so that slipping on the bath brickwork is avoided. The sampling bottle is also rigidly secured at bottom on a rubber pad and at the shoulder by means of a rubber covered retort stand ring clamped tightly. The long " pick-up " tube enables different parts of the bath to be reached either on the surface or at any depth. (It is desirable, after filling the bath afresh, to sample at two or three depths to ascertain the extent of mixing of acid and water.) The bend at the end of the pick-up tube enables a sub-surface sample, free of surface scum and dirt, to be obtained. A light gauge iron or copper — preferably copper — tube could be used in an emergency to replace a breakage of the glass pick-up. The suction release cock on the sampling bottle bung enables the pickle which becomes trapped in the pick-up tube during sampling to be released and drained back into the bath. In

9 Hydrochloric acid pickle for purposes other than galvanising may be worked at 100 ozs. per cubic foot as compared with 150 in this paper.

10 Some operators raise the temperature to 30/40° C. by deliberate application of heat, to accelerate the action.

fitting up this apparatus, care should be taken to get a suction bulb which *will* lift the pickle into the sampling bottle. A small suction pump, obtainable from suppliers of medical equipment, may be used in place of the bulb.

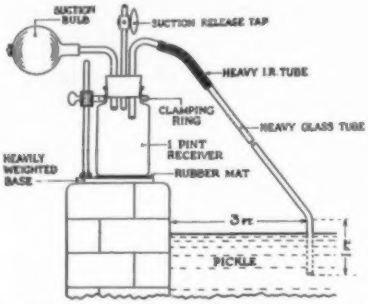


Fig. 5—A convenient form of sampling apparatus.

The bath sample, or a portion thereof, should preferably be filtered through a No. 4 Whatman or other quick filtering paper and diluted to 10 times its volume. This diluted solution (hereinafter described as "the diluted sample") is of convenient strength to enable volumetric titrations to be carried out with deci-normal solutions. For the acidity titration N/10 sodium carbonate is used with methyl orange. The momentary presence of ferrous carbonate during titration and the slightly greenish-yellow end point can be ignored. The iron concentration can be determined in the usual way by reduction and titration with N/10 potassium dichromate in presence of added hydrochloric acid (it is not wise to rely upon the presence of *bath* acid) using potassium ferricyanide as an external indicator. It is hardly necessary to remind the chemist that the volume of the diluted solution taken for assay should be related to its strength—for example, 10 c.c. for a nearly new bath for the acid valuation—whereas the same bath would need 25 c.c. for the iron titration, and *vice versa*. Likewise he will remember that his assay solutions were diluted ten times. It should be remembered that an increase of one ounce per cubic foot of iron corresponds to a drop of 1·3 ozs. per cub. ft. of hydrogen chloride Thus, if an iron titration test should show a rise of 4, then the corresponding acid drop will be $(4\times1{\cdot}3)$ ozs. per cub. ft. This should of course, check up on actual titration.

III. *Artificial Drag-out.* — The following method illustrates the calculation of the amount of artificial drag-out required to restore bath strength and depth by subsequent addition of conc. acid.

Let the concentration be 100 ozs. per cub. ft. Let the standard level be 84 inches and let z be the amount of drag-out required, *i.e.*, $z=(84-x)$ where x=the depleted level. Then, since concentration required is 150, the topping up equations become.

$$150=\frac{x.100+318(84-x)}{x+(84-x)}$$

whence $x=65$ inches (approx.)
Hence pickle must be pumped out until the residual depth is 65 inches This may be checked thus :—

$$x=65,\quad y=100,\quad z=19$$

$$C=\frac{6500+(318\times19)}{84}$$

$$=150 \text{ ozs. per cub. ft.}$$

IV. *Bath Temperature and Restrainers.*—The rate of dissolution of iron and/or iron oxide in hydrochloric acid depends very much upon the temperature of the bath, as well as upon its strength.

At 15° C. the action is neglible.
20° C. ,, ,, slow.
25° C. ,, ,, reasonably fast.
30° C. ,, ,, very much faster

At 35° C. and above the action is violent, especially with high acid concentration and gets out of hand. The pickling action itself evolves heat, but this will be helpful in warming up a cold bath and is not likely to be excessive. In some quarters the use of immersion heaters is advocated ; these would, of course, be brought into action after a spell of bath idleness during severe weather. The use of well-fitting covers, suggested elsewhere in this paper for other reasons, would reduce heat losses from the open surface of the pickle and might be tried in plants where working is intermittent and where there is difficulty in maintaining the temperature. Bath temperature should be taken frequently ; maybe every two hours with a new plant ; experience alone will determine how often this should be done. The Fahrenheit temperatures corresponding to the Centrigrade figures given above are 59°, 68°, 77°, 86°, 95°, respectively. Thus at ordinary room temperature (60° F.) action is negligible.

The use of restrainers is not dealt with in this paper ; no very definite information on their efficacy appears to be available if used with unheated hydrochloric acid pickle (sulphuric acid pickles are used hot). The purpose of a restrainer is to promote a preferential action of the hydrochloric acid upon the *scale*, rather than upon the metal itself, with consequent saving in acid and avoidance of undue surface roughening. The efficacy of a restrainer could only be assessed by long carefully recorded trials with and without it—say twelve months—due correction being made for tonnage and for other variable factors.

Errata

In some copies of the last issue the effect of damage to some type has been noted in Footnote 2 of the above article, on page 298. In order to make this clear the footnote is reproduced here :

2 The weights of a litre of hydrogen, air and hydrogen chloride respectively, under standard conditions of temperature and pressure are 0·09, 1·3 and 1·64 grams ; that of a litre of water being 1,000 grams. These figures are also correct if read as ounces (Av.) per cubic foot.

Titanium Metal

SMALL-SCALE manufacture of titanium metal has been announced by the du Pont Company, Wilmington, Del. A pilot unit of 100 lb. daily capacity is said to have been successfully placed in operation at the Newport, Delk plant of the Pigments Department. This is believed to be the first time ductile titanium metal has been produced for commercial exploration, although it has been produced previously for research purposes.

Titanium is a low-density, silver-white metal, between silver metal and stainless steel in colour. In ductile form it possesses an excellent strength-weight ratio and good corrosion-resistant properties. This means that in comparison with such common metals and alloys as iron, copper, silver, steel, and brass it is relatively light. In its ductile form it is readily workable and relatively pliable. Tests have shown that, without protection, its resistance to corrosion by salt water and atmosphere is excellent and that it withstands the effects of most chemicals better than most other structural metals. In its unalloyed form, it compares approximately with 18-8 chromium-nickel stainless steel.

Reports indicate that an early major use may be in high-speed airplanes and other forms of transportation. It may go into into corrosion-resistant equipment and industrial machinery such as printing presses and textile equipment.

They indicate that the properties of titanium are such that it may be used for reciprocating mechanical parts and in jet engines where heat and pressure are great.

From *Mech. Eng.* **70**, 1948, 910

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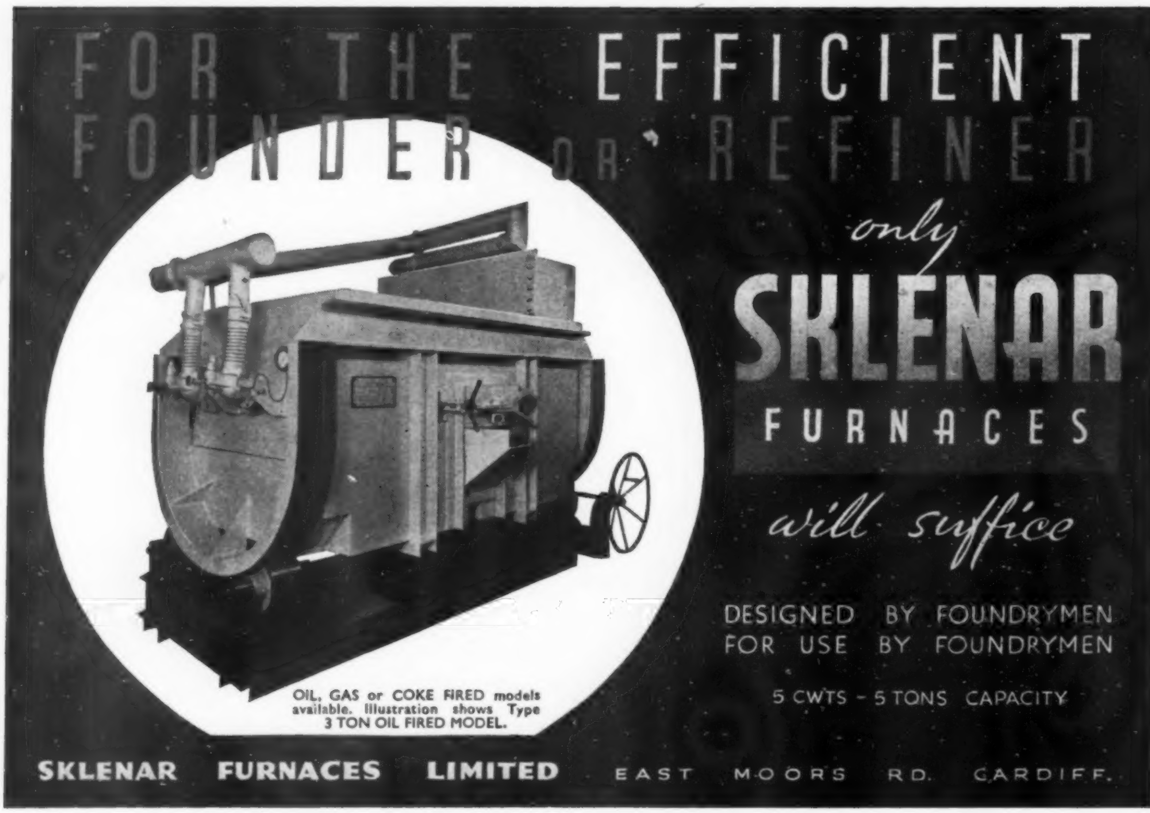
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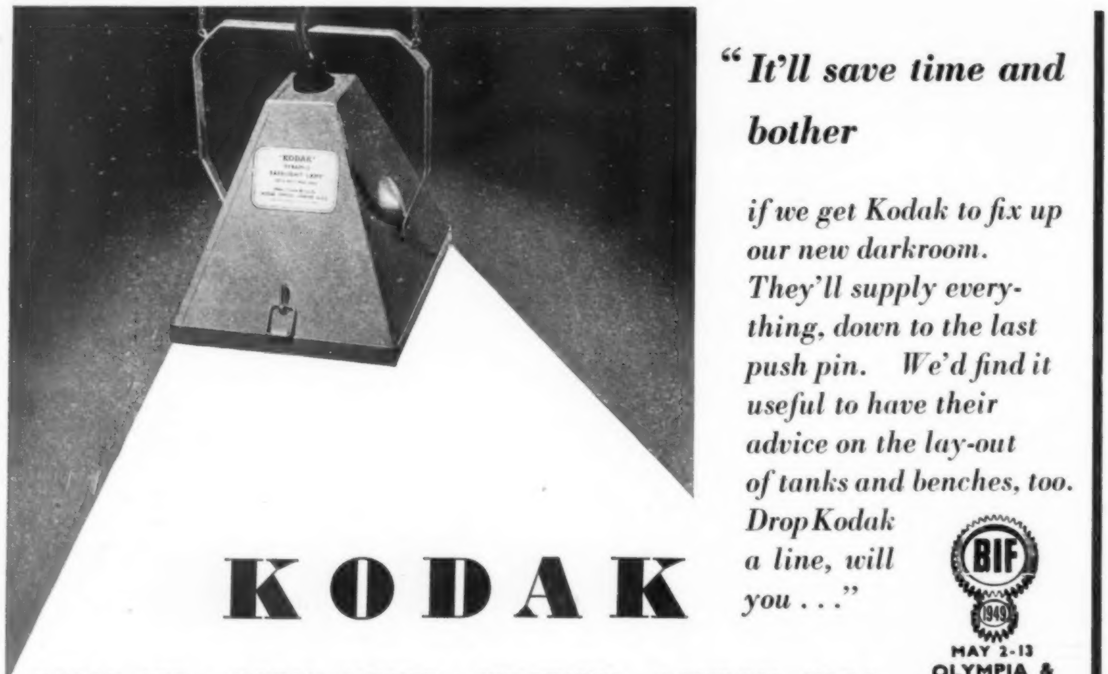
OIL, GAS or COKE FIRED models available. Illustration shows Type 3 TON OIL FIRED MODEL.
SKLENAR FURNACES LIMITED EAST MOORS RD. CARDIFF.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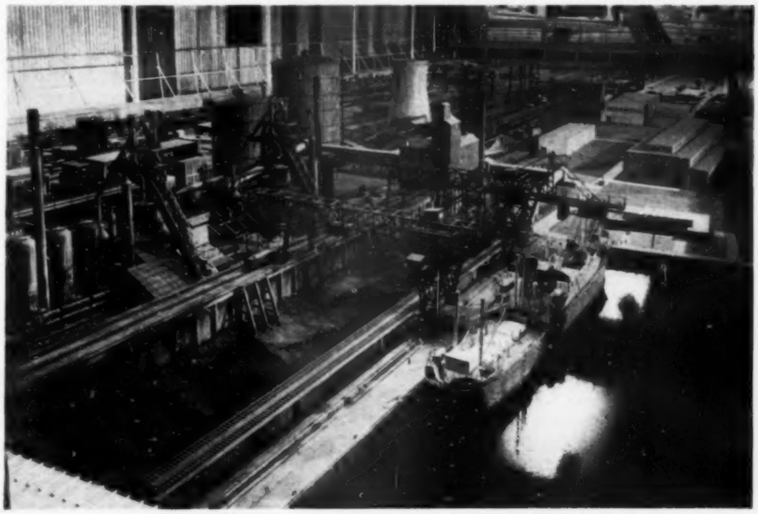
The British Industries Fair

On May 2nd the British Industries Fair opens for the twenty-eighth time, and from then until May 13th, when it closes, thousands of visitors will view the exhibits at Earl's Court, Olympia and Castle Bromwich. Of these, many will merely be displaying a general interest in the progress of British industry, and it is good that such an interest exists. However, in view of the economic position of the country, as outlined in the recent Economic Survey, the importance of the Fair as a shop window, in which the products of British industry are displayed before the buyers of the world, is paramount. As we are more closely connected with the heavy engineering section, this pre-review is confined to some of the items of interest displayed at Castle Bromwich.

FROM 1915 onwards, the British Industries Fair was held annually until 1939, and it had, by then, established itself as one of the leading trade fairs of the world. It was recognised as the shop window of British Industry, where buyers from every country in the world could see what Britain had to offer and could note the progress that was made from year to year. The immediate post-war years were, for this country, years of reconversion from war-time to peace-time activities—pots, pans and prefabricated houses were absorbing the output of the aluminium works, which had previously been taken up by the aircraft factories, and steel was being used once more for building, motor-cars and tractors, power plants and a host of engineering products destined to advance the living standard of the world. In such circumstances, the revival of the B.I.F. in May, 1947, was no mean achievement and it played a worthy part in increasing our export trade. Those were, of course, the days of the seller's market which is now fast disappearing and it is obviously more important than ever that the best use should be made by industry of the Fair as a means of showing what it can produce in the way of high quality and yet reasonably priced goods.



Courtesy of The British Iron and Steel Federation.

Working model of an integrated steelworks, measuring 60ft. × 24 ft. This is believed to be the largest working model in the world.

The term "window dressing" has, in recent years, acquired a rather derogatory meaning. It has been used to indicate the setting up of a somewhat decorative and handsome looking facade to cover up the deficiencies of the interior but, in connection with the B.I.F. it should be emphasised that it retains its original significance, namely the setting out in an attractive and interesting way of the high quality goods which are being made from day to day. If it were not so, the Fair could hardly have continued in existence. Time was, of course, when there was a tendency amongst British manufacturers to regard finish on their products as something rather unnecessary, the view being held that a sound, well-made product which performed its designed function reliably and with every satisfaction was all that was required. True enough, attention to finish paid at the expense of attention to quality is an obvious fore-runner to lost custom, but it is the well-finished article, designed with regard to artistic appearance as well as functional operation which attracts the buyer. That this is being realised to an increasing degree is obvious from the improved appearance of many products and the interest in finishing is emphasised by the decision to hold an Industrial Finishes Exhibition at Earl's Court in September of this year.

The visitor to the Castle Bromwich section of the Fair will no doubt realise that, from the engineering aspect, the notice—often displayed in shop windows—"If you do not see what you want in the window come inside"—applies with even greater force than in its more usual application. In the limited space available it is obvious that the larger engineering projects cannot be displayed except by means of models or photographs, although there are one or two outsize exhibits as will be noted in the following brief description of some of the stands. The wide range of products manufactured by many exhibitors preclude the possibility of displaying them all, but members of the firms' staffs will be available to give more detailed information on their many-sided activities and in many instances visitors will be given facilities to see the larger projects for themselves at the works.

To do justice to the many exhibits displayed at Castle Bromwich would require more space than can be devoted to them in a supplement such as this. We must be

content, therefore, to mention some of the many exhibits which are likely to be of interest to readers.

Steel

The efforts of the British steel industry to increase output, in order to assist the engineering and other steel consuming industries in their export drive, have been truly remarkable and there will be few stands at the Fair which do not include some exhibits made from steel.

The industry as a whole is represented by the British Iron and Steel Federation whose Stand D.631/530—D.633/532 is intended to provide a Central Information Office for the member firms. Apart from accommodation for discussion and consultation with buyers, the main feature of the Federation's stand will be a large working model of a completely integrated steelworks. This model, 60 ft. × 24 ft., is believed to be the largest working model in the world, and shows how a modern steelworks may be laid out.

An exhibit which will undoubtedly strike the eye as one approaches the English Steel Corporation's Stand D. 623 is the hollow-forged high-pressure boiler drum which occupies the whole of one side. Complete with nozzles, tube holes and manhole covers, this drum is 26 ft. long, 3 ft. bore, and weighs over 13 tons. Although limitations of space permit the showing of only a small drum, it is a useful example of the hollow-forged type of boiler drum with bores up to 5 ft. dia. and weighing up to 65 tons, in the manufacture of which English Steel Corporation have been leading specialists for many years.

Another striking exhibit is a series of aeroplane and lorry crankshafts, finish-machined by E.S.C. from their own drop forgings. Springs for road vehicles are also shown, but here again space does not permit the exhibition of the entire range of E.S.C. coil and laminated springs which are produced in a very modern plant.

Exhibited for the first time is a range of rock bits for the deep drilling of boreholes for oil. Forged steel kellies, drill collars and substitutes are also shown. These are made by E.S.C. under licence from English Drilling Equipment Company of Bilbao House, 36, New Broad Street, E.C.2, and as in the past they have been almost entirely a monopoly of U.S.A., their production in this country is a great dollar-saver.

The central feature of Stand D.400, that of Exors. of James Mills, Ltd., is a full scale model of an express locomotive emerging from a tunnel and running on track fitted with Macbeth spike anchors. These are a recent development for fastening flat bottom rails to wooden sleepers and are much in advance of any comparable rail fastening. Also displayed are Mill's jaws for securing flat bottom rails to steel or cast iron sleepers. Both types of fastening are of exceptional interest in view of the recently announced policy of converting British main lines to flat bottom rail track.

Special emphasis is placed on the company's grooved pins and studs, for which there is an enormous potential world demand for replacing taper pins, screwed pins, etc., and a representative range of components in which they are incorporated is displayed. Other exhibits include examples of the range of bright drawn bars and special shapes; keys, pins, studs and cotters; and, of course, the well-known Ledloy free machining steels.

On Stand D.419 and 320, Firth-Vickers Stainless Steels, Ltd. are making a display of their well-known products, including stainless and heat-resisting steels in the form of sheet, strip, bar, castings and forgings. Stainless steel also forms the basis of an attractive display on Stand D.528, where Lee of Sheffield, Ltd. are showing examples of their stainless steel strip and wire, and of a wide range of articles made from them.

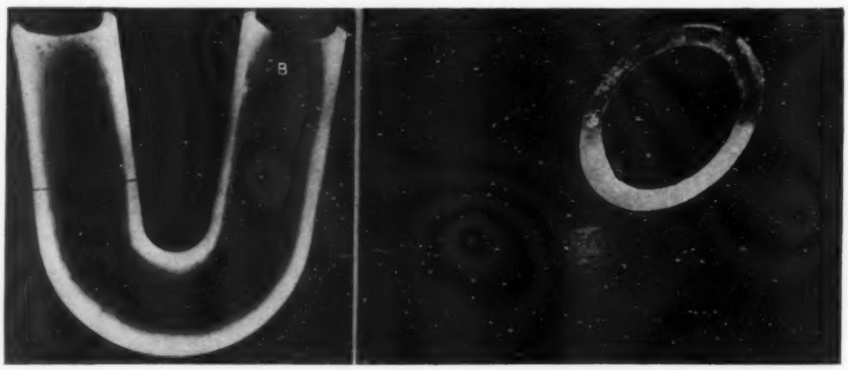
The exhibits to be shown by British Rolling Mills, Ltd., on Stand D.208 include their Hitenspeed free-cutting, high tensile, high impact steel, sold in bar form, which has proved an admirable substitute for much more expensive steels used in the automobile and light engineering industries. Other exhibits demonstrate the many uses to which their mild and deep drawing quality steel strip are put. Special attention is drawn to the recently installed heat treatment plant for the normalising, tempering and heat treatment of bars. The plant is fully mechanised and it is hoped that its installation will result in improvement in both quality and quantity of material handled.

There is still a demand for wrought iron for various purposes and on Thos. W. Ward's Stand D. Outdoor, their subsidiary company Lowmoor Best Yorkshire Iron, Ltd. are represented.

The attention of visitors is also directed to the stands of Walter Somers, Ltd. (D.517), makers of steel forgings; the Lancashire and Corby Steel Manufacturing Co., Ltd. (D.511 and 408), cold rolled steel strip; and Richard Thomas and Baldwins, Ltd. (D.301 and 200 and D. Outdoor), manufacturers of sheet in a wide range of materials, and of aluminium alloys in the form of building materials and structures.

Ferrous Castings

This year on Stand D.630, Edgar Allen & Co., Ltd. will devote more space to the steel foundry department than in previous years, and there will be a range of well-finished stainless steel castings, as well as a number of good examples of the steel founder's art when practised



Courtesy of The David Brown Foundries Company.

Radiograph of cast steel bend for high pressure steam showing the presence of a large number of trapped sand inclusions confirmed by the section taken at the position indicated.

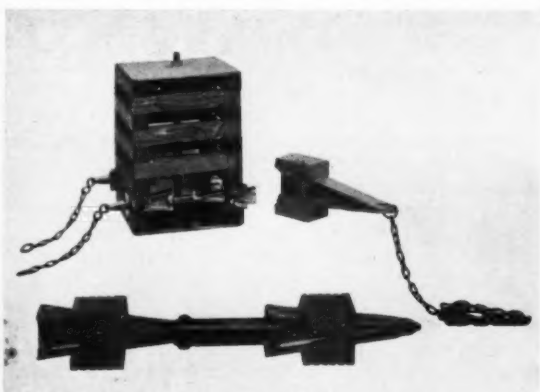
upon castings of ordinary steel. Permanent magnets will be shown, and an interesting and unusual feature will be a number of three-dimensional photographs, or " deep pictures " as they are called, which have a spectroscopic effect showing the particular product photographed in *three* dimensions, instead of the usual two. It is believed that Edgar Allen & Co., Ltd. are the first steel firm to exhibit pictures of this type for their products, and the photographs will show a large rotary cooler, a large jaw crusher, examples of the Company's trackwork, typical steel castings, and a group of permanent magnets.

On Stand D.138 is given an impressive picture of the activities of the David Brown Companies at Huddersfield, London, Penistone, Coventry, and Salford. Of interest to visitors with a metallurgical bias will be the exhibits of David Brown-Jackson, Ltd. and of The David Brown Foundries Company. The products of the former are typified by a display of heavy iron, and acid open-hearth steel castings, rolls and gear units.

The David Brown Foundries Company include amongst their exhibits an interesting selection of carbon steel, stainless steel, high tensile steel and heat-resisting alloy steel castings for aircraft, transport, marine, oilfield, refinery and industrial purposes. Although not ferrous, mention may be made of the Taurus bronze sand and centrifugal castings which will be displayed. Of especial interest on this section of the stand is the centrepiece, illustrating the use of radiography in the foundry.

In 1937 David Browns were the first steel founders in the country to instal X-ray equipment, and they established a further lead during the war when they acquired a radium source. The Penistone foundry now operates three X-ray sets (two of 220 kv. and one of 400 kv.) and two radium sources (of 200 and 30 milligrams). The associated foundry at Salford, David Brown-Jackson, Ltd., employs 200 milligrams of radium.

A selection of steel castings for use in a wide variety of industries will be displayed by K. & L. Steelfounders and Engineers, Ltd., on the stand of the 600 Group of Companies (D.604 and D. Outdoor). The exhibits include locomotive's wagon castings, castings for the electrical industry and " Coborn " cast steel anvils. The Widnes Foundry and Engineering Co., Ltd., who specialise in castings and fabricated vessels for the chemical, gas, oil and allied industries will have on show, on Thos. W. Ward, Ltd's D. Outdoor Stand, a typical product for chemical work.



Courtesy of Hale and Hale (Tipton), Ltd.

Chock release and wedges in Blackheart malleable cast iron.

The days when cast iron was regarded, from an engineering standpoint, as a material to be viewed with a certain amount of suspicion are now receding rapidly, thanks to the immense amount of development work carried out by industrial laboratories and The British Cast Iron Research Association. Development of alloy cast irons, malleable cast iron and straight cast irons with greatly improved structures have led to an increasing use of the material in engineering construction.

Blackheart malleable iron is now firmly established and on Stand D.609 and 508 Hale and Hale (Tipton), Ltd., are showing examples of products in this material, which is used in heavy electrical engineering, railways, commercial vehicles and agricultural machinery. Also on show will be Hale's manhole step-irons, made to B.S. 1247/1945, of which more than a million have been made since the introduction of the specification. Another feature of the display will be colliery products, including various examples of wedge-type and screw-type pit props. Current production includes a substantial overseas order for wedge-type props.

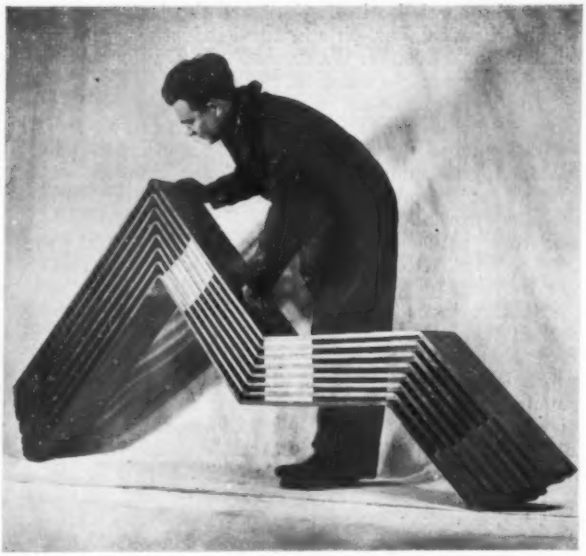
A recent development of the company is Permalite, a pearlitic malleable cast iron which is hard wearing and freely machinable and has many uses previously reserved to steel. With a tensile strength of 33–35 tons/sq. in. and an elongation of 6–8%, it is claimed to be specially suited to the production of brake drums, gear blanks, bushings, pressure castings and other types of casting required to resist shock and abrasion.

The centrifugal method of casting pipes in water-cooled metal moulds was developed by the Stanton Ironworks Co., Ltd. in 1922, and since that time over 19,000,000 spun pipes have been made. On Stand B.626/719, will be displayed spun iron pipes ; special castings ; castings ; concrete-lined spun iron pipes ; three types of flexible joints for gas and water mains ; and a range of pig iron made in the company's blast furnaces. An important feature of the display will consist of historic pipe exhibits ranging from the first to the nineteenth centuries. There will also be a projection of a short film showing the manufacture of spun iron pipes.

Sharing Stand D.529 with the associated company, Varatio-Strateline Gears, Ltd., Follsain-Wycliffe Foundries, Ltd. will be exhibiting examples of castings in a variety of materials. These will include a group of Wycliffe Blackheart malleable iron castings ; various examples of castings in E.V. heat-resisting nickel-chromium steel, which will withstand temperatures up to 1,175° C. and maintain their strength at elevated temperatures to a marked degree ; castings in C.Y. abrasion resisting alloy which when used as brake blocks gives a life of 2¼–3 years compared with 3–4 months for ordinary cast iron ; and Wynite high-duty cast iron, used extensively for castings requiring a very close grain.

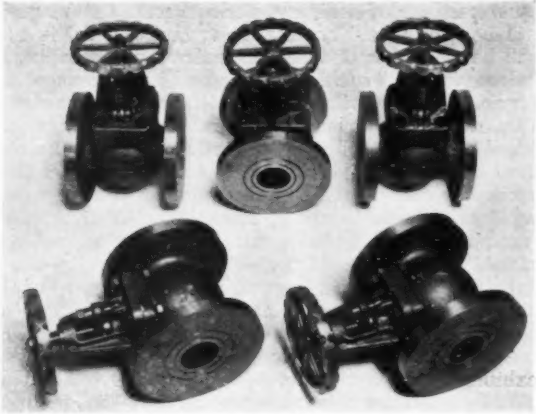
Examples of mild steel castings and pressings treated by the company's Penetral process will also be on view. The beneficial effect of such treatment on such things as cyanide pots, superheater parts and pyrometer sheaths is demonstrated by the increase in life which results.

Further examples of Blackheart malleable iron castings, as used in the engineering and automobile industries, are shown on Stand D.513 and 410 of Ley's



Courtesy of Thomas Bolton and Sons, Ltd.

Large shaped copper bus-bars made from 7 in. × $\frac{3}{16}$ in. hard drawn high conductivity copper.



Courtesy of Langley Alloys, Ltd.

Globe valves in corrosion-resisting alloy.

MALLEABLE CASTINGS CO., LTD. In addition there will be a display of castings in " Lepaz " pearlitic malleable iron which, after vigorous tests has proved eminently satisfactory in numerous applications where the desired properties include high strength, great rigidity, wear resistance and high fatigue value. These properties have been utilised extensively in the automobile industry.

Also of interest is Stand B.517 and 416 of THE STAVELEY IRON & CHEMICAL CO., LTD., makers of pig-iron, sand-spun, metal-spun and vertically cast pipes, flexible and patent joints and chemicals and by-products.

A miscellaneous selection of castings will be displayed by the JOHN THOMPSON FOUNDRY COMPANY, one of the associated companies of JOHN THOMPSON, LTD., on Stand D.521/418. Recently constructed, the foundry is largely mechanised and is capable of making castings from 2 lbs. to 25 tons in weight.

On the FERRANTI Stand (C.615/514), a representative range of castings produced in the company's foundry will be shown. These will include specimen castings in " Nomag," a non-magnetic grey cast iron widely used in the electrical industry for a variety of castings such as cable boxes, alternator end rings, switch covers, resistance grids, etc.

Copper and Copper Alloys

The counterpart of the British Iron and Steel Federation, on the non-ferrous side, is the BRITISH NON-FERROUS METALS FEDERATION, the representative organisation of the British non-ferrous metals industry. Inquiries regarding all aspects of the industry may be made at Stand D.219, where Federation staff will be available throughout the Fair.

A visual presentation of all the applications of copper and copper alloys in all industries would require an exhibition as large as the British Industries Fair. The COPPER DEVELOPMENT ASSOCIATION's Stand D.230, is, therefore, restricted in scope to the display of a few of the important uses of copper and copper-bearing materials in such recognised fields as electrical and mechanical engineering, chemical engineering and building technique, and in less spectacular but equally interesting manufactures, such as boots and brushes, clock parts and spectacle frames. Information on these and all other uses of copper and copper alloys will be given by the technical officers of the Association, who will be on duty at the stand throughout the duration of the Fair. Requests for the Association's technical publications, issued free to *bona fide* applicants will be also accepted on the stand.

In the construction of the stand itself copper tubes and strip are skilfully used to form a structure which is both functional and attractive. The arrangement allows the use of illuminated display panels arranged in an arc, with ample floor space in front of them which invites the onlooker to make a close examination of the exhibits. In addition, a gleaming copper printing roller relates to a handsome curtain printed to the pattern etched on the roller.

Established as long ago as 1783, the firm of THOMAS BOLTON & SONS, LTD. to-day occupies a prominent position in the copper side of the non-ferrous metals industry. Although such items as copper ingots, electrical castings in high conductivity electrical copper, and cored and solid chill cast phosphor bronze bars suitable for bushings appear in the list of the company's products, the output consists mainly of copper and copper alloys in the wrought form. The range of compositions covered embraces almost the entire field of copper alloys and the forms in which they are available include plate, sheet, strip, rolled and extruded bars and sections, tubes and wire. In addition cemented carbide products are made in B.T.H. " Ardoloy " ; these include extrusion, cold drawing, heading and presswork dies. Whilst the requirements of the mechanical engineer are catered for in a comprehensive manner, the company has devoted special attention to the requirements of the electrical industry as will be seen from the exhibits displayed on Stand D.125. These include copper, brass and bronze wire and strip ; trolley wire sections ; commutator segments in Combarloy ; " Bush " brand chill cast phosphor bronze bars ; plain and gilled tubes ; rail bonds for electric traction ; two- and three-pole equaliser bars ; tungsten carbide dies ; extruded and drawn

sections ; and finished and partly-finished machined parts.

The dignified and handsome structure in "Delta" bronze No. IV, and "Delta" No. 2 silver bronze which forms the centre piece of the DELTA METAL COMPANY's exhibit, on Stand D.311, very suitably illustrates the application to architectural metal work of the company's well-known alloys.

Although the principal business of this old-established firm is the supply of non-ferrous metals in rod and bar form to practically every branch of engineering industry, the use of extruded mouldings for decorative work is continually increasing, and an infinite variety of shaped bars for the manufacture of shop fronts and showcases, doors and casements, gates, grilles, signs and fascias, etc., and for all kinds of art metal trim and fittings, is on view.

The exhibit includes samples of rods in "Delta" high-speed turning and screwing brass for repetition work, specimens of hundreds of purpose-made extruded rods of special shapes, and bars in "Delta" high conductivity copper, "Delta" high strength bronzes, naval brass, yellow metal, aluminium bronze, and other alloys. "Delta" welding rods for gas welding are also on view, as are examples of forgings and hot pressings in "Delta" bronze No. IV, brass and yellow metal. Extruded hollow rods and sections for window manufacture ; rolled and drawn brass, copper and gilding metal strip and wire ; and specimens of bent wire goods are also to be seen, these latter being the products of the associated firms, Messrs. Extruded Metals Co., Messrs. Moore Bros. (Birmingham), Ltd., and Messrs. Heaton & Dugard, Ltd.

The METALS DIVISION of IMPERIAL CHEMICAL INDUSTRIES, LTD., covers the light alloy field as well as that of copper and its alloys, but the light alloy exhibits will be dealt with in the appropriate section. On the copper side the products of the Division are almost too numerous to mention, covering as they do such materials as copper, alloyed copper, brass, bronze, the complex bronzes and the nickel silvers in all varieties of shapes and sizes. Progress is an essential of any industry and to this end the Division's research department has played a considerable part in the development of new alloys and the improvement of existing ones.

As one of the largest manufacturers of condenser tubes, considerable attention has been devoted to the problems of corrosion and erosion in condenser tube alloys and one of the main exhibits on Stand D.409/308 is a model, representing the inlet end of a condenser, which will be used to demonstrate some operating conditions which tend to produce failure of condenser tubes through erosion, corrosion or impingement attack. Sections of tubes which have failed in these conditions will be displayed.

Also featured will be an exhibit illustrating the extensive investigation work associated with copper or aluminium alloy faced roofing panels, and with the adhesives for bonding the layers which make up these units. Their behaviour under rapidly varying temperatures will be shown.

The products of LANGLEY ALLOYS, LTD. exhibited on Stand D.210 indicate the wide fields of application covered by their castings, stampings, forgings and bar in special bronzes as well as the castings in nickel base alloys which they now produce in considerable quantities. This company manufactures an extensive selection of materials ranging from commercial gunmetal to such materials as the high strength aluminium bronzes of the "Hidurax" range and the special corrosion resistant materials of the Langalloy "R" Series. They have a wide experience of the manufacture and application of these alloys and offer a complete technical service to engineers and designers in all spheres of industry.

Exhibits of particular interest as developments of the past year are the chemical valves displayed. These, and such items as pump impellers and cast pipe fittings, may be made, according to service requirements, in a range of nickel alloys, including Monel, nickel and the Langalloy "R" Series, which possess a very high degree of resistance to corrosion.

In the field of copper base alloys the high strength Hidurax aluminium bronzes which are highly resistant to abrasion and corrosion by sea water and many normally corrosive waters are displayed in many forms, a particularly interesting example being the gas turbine compressor blades which will be shown.

Other copper base alloys displayed include Hidurel 6, combining high strength with high electrical and thermal conductivities both at room and elevated temperatures ; Hidurel 5, another high conductivity alloy used for automobile valve guides ; and P.N. phosphor bronze whose corrosion resistance is enhanced by an addition of nickel.

A further interesting exhibit is a range of standard pipe fittings for use in handling foodstuffs, made in Hidurit 18, a low-zinc nickel silver.

Much intensive backroom research has gone into the production of Narrmac, an entirely new aluminium bronze alloy being exhibited by MCKECHNIE BROS. on Stand D.612. This was developed in collaboration with Rolls Royce, Ltd., and Messrs. N. C. Ashton, Ltd., of Huddersfield and was produced primarily for use in the manufacture of blades and similar parts for jet engines. It is obvious that the high standard of reliability and performance and the great strength under all operating conditions which Narrmac had to have for a job as tough as that will find for it many uses in other fields of industry.

Extruded sections in brass and bronze form a big part of McKechnie's output and the high degree of accuracy attained makes them suitable for the manufacture of small finished parts. Among the products to be displayed are : Extruded brass and bronze rods and sections ; white metal rods and sections ; brass bronze and white metal stampings ; chill cast phosphor bronze and gunmetal bars for bushes and bearings ; non-ferrous metal ingots ; antifriction metal ingots ; granulated cupro-nickel ; terne metal ingots ; nickel silver ingots ; "Narrmac" aluminium bronze rods ; welding bronze rods, and wire in coils.

Apart from the display of the firm's well-known "Yorkshire" copper housing tubes, "Yorcalbro" (aluminium brass) and cupro-nickel marine and power station condenser tubes with which the main and imposing feature of the YORKSHIRE COPPER WORKS Stand (B.727/634) are panelled, quite a number of new and interesting exhibits are being shown.

Two 6-in. bore bent and flanged pipes are displayed, one in "Yorcalbro" and one in "Yorkshire" copper-nickel-iron alloy (B.N.F.M.R.A. Patent No. 577065). These pipes are superseding heavier gauge copper pipes for sea water pipe lines owing to their high resistance to corrosion-erosion attack. They can be worked, either hot or cold, with only slightly more effort than that

required to bend copper tubes. Ordinary brazing or silver brazing can be used for jointing the "Yorcalbro" pipes whilst autogenous welding can be used on the copper-nickel-iron pipes.

Of special interest are a number of tubes removed from service and sectioned to show the satisfactory manner in which they have behaved. Included in these are a marine condenser tube in "Yorcalbro," after 19 years' service, a copper water service pipe after 20 years' underground service, and a series of tubes in various alloys after service in a sugar factory vacuum pan.

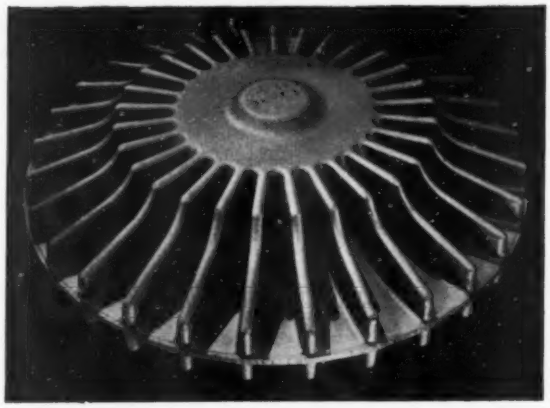
In addition to examples of different types of corrosion attack, the most suitable "Yorkshire" alloys for the oil industry, cane and beet sugar factories, engineering pipelines, refrigeration and marine services, etc., are displayed. The 0·005-in. internal diameter restrictor tube in the refrigeration tubes display panel contrasts with the 24-in. diameter seamless copper tubes which tower on either side of the main feature of the stand.

Light Alloys

The manner in which the aluminium industry has solved the problem of utilising, for peacetime products, the large amount of plant set up to cater for a greatly expanded wartime aircraft industry has been a source of satisfaction to many. In spite of the increasing use of secondary aluminium, imports of virgin metal have to be made to supplement the home production of some 30,000 tons per annum. The chief sources of home produced aluminium are the Highland plants of The British Aluminium Co., who are exhibiting on Stand D.605. Apart from the production of virgin metal British aluminium produce considerable tonnages of sheet, strip and section material. A recent addition to the company's products is the Positive-Grip-Pattern (P.G.P.) Treadplate which has a wide variety of marine and industrial applications. Exhibits include: Large plate (now available in sizes up to 30 × 6 ft.); a small pylon-type structure symbolising the 6,000 different sizes and shapes of extruded section and three dimensional models illustrating "Aluminium Economies." Shown as part of the stand structure, "Rigidal" corrugated aluminium sheet makes its first exhibition appearance. Combining lightness and strength with excellent corrosion resistance, it makes an ideal roofing material for industrial buildings while its high thermal efficiency makes it eminently suitable for use in tropical climates.

The remarkable progress of aluminium as a building material is illustrated on the Almin Stand, B.723, where Structural and Mechanical Development Engineers, Ltd., an associated company, will feature films showing the construction of buildings embodying a greater or lesser amount of light alloy in their construction. The audience will be able to see a complete bay of an Alframe Transportable Storage building erected by six men in less than 15 minutes without mechanical assistance. Alframe aluminium alloy roof construction is in great demand, particularly by textile and food processing factories where the fact that condensation dripping from the roof neither stains nor harms any materials with which it may come into contact.

Southern Forge, Ltd., on the same stand, are showing extrusions, tubes and forgings in aluminium alloys whilst Warwick Production Co., Ltd. will display hotel and canteen furniture and food containers in aluminium alloys. Renfrew Foundries, Ltd., specialists in light alloy castings will also be exhibiting on this stand.



Courtesy of High Duty Alloys, Ltd.

Double sided impeller for Rolls-Royce "Nene" jet engine, stamped in "Hiduminium" R.R.58.

On Stand D.232, High Duty Alloys, Ltd. will be showing photographs and examples of some of their recent products. Practically the entire range of aluminium alloys is produced by this company in the form of extrusions castings and forgings. The development of the gas turbine, particularly of the axial flow compressor type, necessitated the production of forgings and castings to more stringent requirements and in larger sizes than had hitherto been called for, and a considerable amount of development work was carried out by the company to that end.

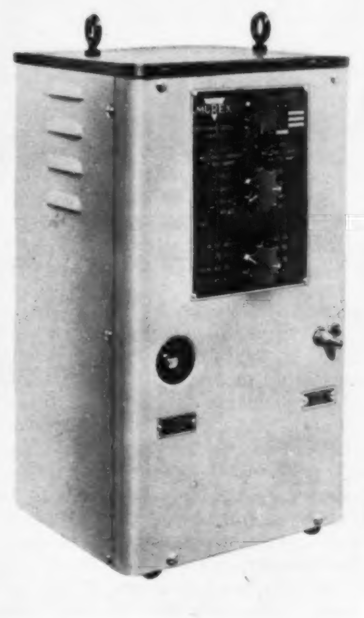
The period of intensive development of new markets and new uses for aluminium is passing, and emphasis is now laid on ability to deliver the goods. For this reason, the Northern Aluminium Co., Ltd. decided to feature their products and manufacturing resources on Stand D.629. The central feature is a half-scale model of one of the company's five hot mills, whilst one side of the stand is occupied by scale models of Northern Aluminium's works at Banbury, Rogerstone and Birmingham. Showcases containing sample forgings and castings are situated in front of photographs showing a 3,000 ton extrusion press, a 45,000 lb. forging

Courtesy o The British Aluminium Co., Ltd.

Positive-Grip-Pattern treadplate.

hammer and gravity die-casting. The main products are sheet and extrusions; the former is represented by a 1,500 lb. coil, whilst a wide range of extrusions comprising several hundred sections is compactly displayed on a moving belt. Five of the largest extruded sections made in this country and a 10 in. dia. tube, the largest made outside the U.S.A. are also on view.

One of the three main exhibits on Stand D.409/308 of the METALS DIVISION OF IMPERIAL CHEMICAL INDUSTRIES LTD. will show how aluminium alloys can be used in coachbuilding to produce vehicles which are strong, light, durable and an economic proposition. This will be of undoubted general interest in view of a recent decision of British Railways.



Courtesy of Murex, Welding Processes, Ltd.

Murex 175 amp. transformer welding equipment.

Courtesy of Sciaky Electric Welding Machines, Ltd.

Sciaky Type S.A.T.75 "Three Phase" spot welding machine.

A further stand to which reference should be made by visitors interested in aluminium alloys is that of REYNOLDS LIGHT ALLOYS, LTD. (Stand D.621 and 520), where examples of sheet, strip, tube, extruded sections and bar will be displayed.

On the magnesium side, F. A. HUGHES & CO., LTD. will be showing on Stand D.307 their full range of zirconium-containing alloys in the form of sheet, extrusions and castings of various types. These alloys possess remarkably good mechanical properties as compared with the normal magnesium alloys. There is also an outdoor exhibit demonstrating the use of magnesium anodes for underground pipe line protection. Buried near the pipe and coupled to it at suitable intervals they provide protection from corrosion by electrochemical processes. They may be concentrated where corrosion is heaviest, are simple and cheap to install and require no maintainance. Hundreds of miles of pipeline in the U.S.A. and in the Near East are effectively protected in this way.

Tin

Tinplate is used as a decorative material in the construction of Stand D.141, housing the exhibits of the TIN RESEARCH INSTITUTE. Improvements in hot-dip tinning of cast-iron and steel are exemplified by a group of specimens which show the Institute's contribution to knowledge of the tinning art. Bronzes are an important outlet for tin and much research has been done by the Institute in the past ten years on the chill-casting of these alloys which find applications in wrought and drawn forms as phosphor-bronze strip for switch springs, foudrinier wires, condenser tubes, etc. Electrodeposition is shown by exhibits of pure tin, tin-zinc and tin-copper alloy coatings.

The Institute's function being ultimately to give information, this side of its activities is emphasised by display of technical literature dealing with each main application of tin.

Welding and Cutting Equipment

The attention of visitors interested in electrical resistance welding is directed to the stands of MESSRS. HOLDEN & HUNT, LTD. (C.618 and C.719), BRITISH INSULATED CALLENDER'S CABLES LTD. (C.318), and SCIAKY ELECTRIC WELDING MACHINES, LTD. (C.222).

On the stand of MESSRS. HOLDEN & HUNT, LTD. will be displayed a complete range of universal spot welders from 5–40 kva. rating.

The wide range of arms, electrodes and tips available makes the machines truly universal. Special attention is drawn to the 15/30 kva. machine, fitted with a B.T.H. Thyratron timer, which is suitable for spot welding aluminium up to $\frac{3}{16}$ in. added thickness, and to the 25 kva. motor-driven automatic spot welder, capable of single spots or continuous welding, which is also available in 15 and 40 kva. ratings.

Recently developed butt welding machines capable of welding light alloys from 16 s.w.g. up to $\frac{5}{8}$ in. dia. rod are to be seen at work. One of the machines is fitted with a special transformer to enable high carbon steel wire to be welded. Two rivet heaters will also be demonstrated, the 12 kw. single head and 25 kw. double head models which are extensively used by constructional engineers.

Of special interest will be the chain making plant which is designed for the production of pulley block chain from $\frac{5}{32}$–$\frac{5}{16}$ in. dia. rod, but which will be tooled up for the manufacture of $\frac{1}{4}$ in. dia. chain.

Resistance welding machines displayed in a section of the BRITISH INSULATED CALLENDER'S CABLE stand comprise a 25 kva. pneumatically-operated fixed-head type of spot welder fitted with built in timing and control gear, suitable for jobbing and repetition work on mild

steel up to $\frac{1}{2}$ in. added thickness; a 10. kva. pedal-operated rocking-head type spot welder suitable for mild steel up to $\frac{7}{32}$ in. added thickness; a hand-operated butt welding machine designed for non-ferrous wire and rod; and a 1 kva. fine wire butt welder, fitted with miniature flood-light and magnifying glass to facilitate the alignment of fine wires.

The rapid increase in the utilisation of resistance welding processes during the last few years has led to an enormous increase in installed kva. on the electrical supply systems in this country and abroad. To satisfy the demand of the electrical supply authorities, Sciaky Electric Welding Machines, Ltd., exhibiting on Stand C.222, have developed a system known as Sciaky "Three-Phase" welding, where the load is taken from all three supply lines with equal loading on each line and at a power factor of 80–90%. Apart from the improvement in the power supply position, this system possesses certain operational advantages.

Sciaky will be also exhibiting an entirely new design of heavy duty projection welding machine, type P.A.100. This plant, rated at 100 kva. nominal, can be supplied for connection either to a single phase supply or a three-phase supply. Two further exhibits are the type S.A.C.25/2, 25 kva. spot and stitch welding machine, and the type R.A.M.U.50 air operated, fully controlled, motor driven longitudinal and circumferential seam welding machine.

The immense increase in the use of arc welding during the war made many people conscious, for the first time, of its tremendous possibilities. Visitors will have an excellent opportunity of seeing a comprehensive range of welding equipment and of discussing technical problems at Stand D.709 (Murex Welding Processes, Ltd.).

One of the most interesting exhibits is the Murex safety device which, on A.C. equipment, automatically reduces the voltage at the electrode holder from 80 or 100 volts down to about 30 volts within a fraction of a second of breaking the arc. Representative examples of petrol or diesel engine driven sets, transformer equipment, and motor generator sets are also being shown.

Included in the electrodes displayed are a number of recent additions to the Murex range. These include the Cinex rod which deposits an easily machinable deposit on cast iron without preheating, and the "Bronze 44" an all position D.C. rod for welding brasses and bronzes (except aluminium bronze) to themselves and to steel. Of particular interest is the "Ferex" rod which is a special hydrogen controlled electrode for welding high tensile steels where cracks are liable to occur in the hardened zone of the parent metal. "Hardex 800" yields an 800 v.p.n. deposit on mild steel and "Hardex C.H.R." has been developed for hard facing parts subject to abrasion at high temperatures.

On the automatic side of fusion welding, the exhibit of Fusarc, Ltd. on Stand C.705 will be of considerable interest to visitors. The company specialises in the manufacture of automatic continuous arc welding equipment suitable for welding any size of article from 2 in. dia. work up to pressure vessels, penstock pipes, crane girders and ships' decks. It is of interest to note that the Fusarc process has, during the current year, been accepted by Lloyds Register of Shipping for Class 1 welding, the highest standard of pressure vessel welding.

The covered electrode wire is fed from a drum, through the current contacts, by an automatically controlled feed arrangement which ensures stable arc conditions throughout the run. The remainder of the equipment consists of jigs and manipulators designed to accommodate the type of work being welded. Technical members of the company's staff will be available, on the stand, to answer questions and tender advice to those interested.

Courtesy of The British Oxygen Co., Ltd.

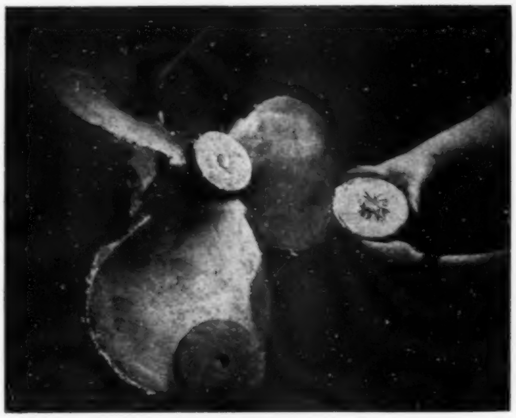
Ceramic hood on Mark III "Argonarc" torch.

Making their debut on the British Oxygen Co's Stand D.201, will be the two new models of B.O.C. hand cutters known as the Cutogen No. 1 and No. 2. These two cutters are the result of extensive research and have been designed to produce maximum efficiency coupled with accuracy in all manual cutting operations.

The Cutogen No. 1 is designed to cut mild steel sections up to $\frac{3}{4}$ in. thick and also sheet metal using the specially stepped nozzle. The Cutogen No. 2 is designed as a general purpose tool, covering the range of the No. 1 and also capable of cutting mild steel sections up to 12 in. thick. Each type incorporates many novel features resulting in perfect balance and economic operation. Both these blowpipes are fitted with the new B.O.C. anti-flashback one-piece nozzles which are designed to give a long and trouble free life.

The latest developments in Argonarc welding equipment, particularly for the welding of aluminium alloys, magnesium alloys, stainless steel, Everdur, etc., are exemplified by the manual water cooled torch (Mk. III), the machine water cooled torch (Mk. IV), and the 300 ampere composite set comprising the high frequency unit, the suppressor and the transformer. These torches allow for much heavier welding currents and in consequence thicker sections of material can be welded at increased speeds. Included in the Mk. III outfit is a new master valve which is incorporated in a rest for the torch when not in use. This automatically cuts off the supply of argon and also the high frequency current when accommodating the torch.

Oxygen cutting by profiling machines is now taking its place in the engineering industry as an economic and precise method of quickly shaping steel to size. Parts previously cast are now profiled out of plate, slabs or sections, thus ensuring a more reliable and accurate job with appreciable saving in time and cost. Oxygen profiling is also used extensively for the preparation of plates for fabrication by welding. As examples of speed and precision it can be stated that 1-in. plate can be cut at a rate of 12 in. or more per minute to an accuracy of



Courtesy of The Morgan Crucible Co., Ltd.

Bronze casting showing use of plumbago knock-off riser plate.

$\frac{1}{64}$ in. or less depending on the size and condition of the job.

On Stand D.739/638 HANCOCK & Co. (ENGINEERS), LTD. will include amongst their exhibits one of their "U" arm profiling machines. This type of machine is made in four sizes for cutting steel up to 8 in. thick and still greater thicknesses can be cut on larger machines. The tracer head incorporates five different forms of drive requiring wood, metal or strip templates, or for working from a drawing without any template. It is believed that these machines are the only ones in the world offering a choice of these five drives. Also exhibited will be machines for special purpose applications.

Rolls for Rolling Mills

The heart of any rolling mill is the roll itself, and with the radical changes which have taken place, by way of increased rolling speeds, the roll founder has been called upon to do the seemingly impossible, but the metallurgists and research workers in this highly specialised branch of the foundry industry have achieved their objective. They have combined the opposed properties of hardness and toughness, heat resistance and wear resistance, rigidity and flexibility, in order to satisfy practically every known mill requirement.

THE BRITISH ROLLMAKERS CORPORATION, LTD., showing on Stand D.205/104 has as operating companies MESSRS. R. B. TENNENT, LTD., MESSRS. THOMAS PERRY, LTD., MESSRS. C. AKRILL, LTD., and MESSRS. BAYLISS ROLLS, LTD. Between them they make most of the rolls produced in this country, and amongst their products are found types to satisfy the most exacting mill engineer. In addition to the large number and variety of rolls exhibited a series of photographs illustrate some of the largest rolls made as well as the plant and processes used in their manufacture. For those interested, a complete range of photomicrographs illustrating various roll structures will be on view.

Foundry Equipment

Sharing Stand D.319 with Messrs. Alfred Herbert, Ltd., DIE CASTING MACHINE TOOLS, LTD. are exhibiting two die casting machines, the M.55A/HF for zinc, lead and tin base alloys, and ADC56, primarily for use with aluminium alloys. The M.55A/HF, with its air-operated plunger, operates on a standard 80 lb./sq. in. air line and consumes only 0·35 cu. ft. of free air at each operation. An important feature is a safety device which shuts off the air supply to the downward stroke of the cylinder until the dies are locked. The ADC.56 aluminium die caster has been designed for the production of small castings up to $2\frac{1}{2}$ oz. in weight. A $4\frac{1}{2}$ in. air cylinder, controlled by a foot-operated valve supplies the pressure to the plunger, and the metal injection cylinder and water-cooled plunger are of nitrided steel.

The foundry equipment selected for exhibition on Stand D.626 (PNEULEC, LTD.) includes a Jarr rollover pattern draw installation, with a turnover plate 38 in. × 48 in., capable of taking a load of up to $1\frac{1}{4}$ tons at 80 lb. pressure and accommodating a pattern draw for $17\frac{1}{2}$ in. A new large Jarr squeeze strip machine, which can take a box up to 864 sq. in. in area is also on show.

Originally designed for use in conjunction with the Pneulec Royer, the Greedigrid provides means for automatically feeding knockout sand from a large hopper, removing the big pieces of scrap and very hard lumps of sand and delivering into a Pneulec Royer for conditioning.

Electro magnetic lifting and separator equipment, suitable for sand cleaning, will be displayed on Stand C.409 by THE RAPID MAGNETTING MACHINE CO., LTD. and on Stand C.605 by ELECTROMAGNETS, LTD.

Foundry equipment made by THE MORGAN CRUCIBLE CO., LTD. will be included in the exhibits on Stand D.305/204. Of the various types of crucible furnace manufactured, the lift-out, bale-out and central axis tilting furnaces will be shown. There will also be a display of crucibles, basins, stands, muffles and covers representative of the wide range of plumbago foundry equipment manufactured.

Morgan plumbago knock-off riser plates are being increasingly used to facilitate the removal of risers from bronze and brass castings as illustrated in the picture of the propeller casting. The plates make a neck in the riser and with 3 in. dia. risers 45% reduction in fettling costs may be attained, whilst with 9 in. risers the figure may rise to 80%. The advantages of plumbago for this purpose lie in the fact that it is not wetted by molten metal, and in its high thermal conductivity.

Items from the "Polford" range of foundry plant, for which THOS. W. WARD, LTD. are sole selling agents are displayed on that company's stand.

Courtesy of Thos. W. Ward, Ltd.

"Polford" patent motor-driven self-contained rotary mixer/miller.

Tubes and Pipes

Reference has already been made to some of the concerns who make metal tubes and pipes in the sections devoted to particular classes of materials. In many such cases, the production of tubes is only one of numerous activities whereas in most of the firms covered by this section, tubes or pipes form the bulk of the output.

In the field of steam piping the name of AITON & Co., LTD., showing on Stand D.608, is well to the fore. Naturally the tendency to use higher pressures and temperatures in generating plant produces its problems in connection with the piping. The exhibits will include examples of plain, corrugated and creased steam pipes in carbon and chrome molybdenum steel. Welding of steam pipes is now established practice and sections through a Corwel joint and a butt-welded joint, together with X-ray and Gamma-ray pictures of butt-welded joints will be displayed. A 15 ft. long forged steel seamless steam receiver will show examples of branch welding and re-inforcing. Other exhibits include Aiton forged steel steam traps and examples of bellows expansion joints.

The REYNOLDS TUBE CO., LTD. shares Stand D.621 and 520 with T. I. ALUMINIUM, LTD. and TUBE PRODUCTS, LTD. Included in the Reynolds' display will be seamless steel tubing in straight lengths for aircraft and all engineering purposes ; seamless steel tubing, cut to length or manipulated, for the bicycle and motorcycle industry, including " Reynolds 531 " tubing cycle components made from " Reynolds 531 " ; also cycle components manufactured from Reynolds Light alloy ; welded steel structures for all aircraft and general engineering purposes ; pressure vessels made from light alloys, suitable for aircraft hydraulic systems, air or gas cylinders, and cylinders suitable for such applications as fire extinguishers, etc.

The design of the T. I. Aluminium section of the stand features aluminium alloy cantilever roof trusses, with purlins and corrugated sheeting of the same material ; also many other uses for building and architecture, such as windows, rainwater goods, etc. Lattice telegraph poles illustrate the use of the stronger aluminium alloys in structural work.

TUBE PRODUCTS, LTD. will show " Tru-Wel " electrically welded carbon steel stainless steel tubes in various gauges ; welded Inconel heat resisting tubes, together with samples of manipulated Inconel products ; specific manipulated operations showing the use of " Tru-Wel " tube for efficient and economic manipulation, together with examples of various products ; and cycle components for sports and roadster type cycles.

The Union Steel Corporation of South Africa recently placed a contract for 240,000 stainless iron rock drill tubes and 84,000 tubes of chrome alloy steel, for the South African gold mines, with ACCLES & POLLOCK, LTD. who are showing on Stand D.619/518. The exhibits comprise : Cold-drawn seamless steel tubes, including stainless and alloy steels ; manipulated and machined tubes ; small-diameter precision tubes ; cycle components ; tubular box spanners ; and tubular sporting goods. Special displays will include tubes for diesel engines, fuel pipes, stainless tubing and fittings for food productions, beer pipes, etc. In the small-diameter range there will be featured a range of hypodermic and blood transfusion needle tubing, multibore and capillary tubing, and the " smallest tube in the world." The sporting goods exhibits, in addition to tubular fishing rods, ski-stick shafts, and golf shafts, will include the latest additions to the range of Apollo tubular archery bows and arrows.

On the same stand BRITANNIA TUBE CO., LTD. are showing close joint, brass cased, stainless welded, and cold drawn welded tubing ; a special moving exhibit showing aluminium and aluminium alloy tubular oil coolers for aircraft ; and anodised aluminium tubes as used for pen caps and pencil cases.

METAL SECTIONS, LTD., the fourth T. I. company on this stand are showing a wide variety of cold-rolled sections in steel, light alloys and other metals for building, transport, furniture and engineering.

Heavier section tubing is displayed by members of the Tube Investment Group on Stand D.617/516. The exhibits of the CHESTERFIELD TUBE CO., LTD. include a solid drawn steel ammonia separator, 48½/34¾ in. outer dia., 23 in. bore, and 15 ft. long, weighing 46,200 lb. ; seamless steel cylinders for compressed gases ; examples of cold drawn seamless steel steam pipes manufactured from carbon and chrome molybdenum steels ; specimens of large diameter seamless stainless steel tubes up to 21 in. dia. ; exhibits of seamless steel boiler and superheater headers, rectangular uptake tubes, spring shackles, diesel engine cylinder liners, electrical switchgear bottles, etc.

The TALBOT-STEAD TUBE CO. are showing Admiralty boiler tubes ; boiler, superheater, flue, bush tubes and steam pipes for locomotives ; high carbon tubing for ball races ; bakers oven tubes ; commercial tubing for pressure and mechanical purposes ; stainless tubes for dairy, brewing, food, chemical, and other trades ; stainless steel tubular fittings ; and bright drawn bars and wire.

Also sharing this stand are TUBES, LTD., whose exhibits include : Tubular forgings, showing how tubes are forged to the shape and size of the finished product, thus saving material and eliminating heavy machining costs ; various tube sections and a model made up from " Tubecon " and " Tubecon " fittings, demonstrating a new method of tubular construction.

MESSRS. STEWARTS & LLOYDS, LTD. in addition to their exhibits on Stand D. Outdoor have a reception stand staffed by representatives of the company on Stand D.511/408. On the outdoor stand a " Universal " building of tubular steel construction will comprise an exhibition hall in which their products and those of their associated companies will be displayed. These include all shapes and sizes of tube (including large diameter tubes up to 72 in. in dia.) ; joints and couplings ; cold rolled strip ; pig-iron ; iron and steel castings ; and a number of photographs showing the contributions made by the company to various industries. The open section of the stand will be devoted to items showing the usefulness of tubing as a constructional material.

An " Arcon " Tropical Building will be in position at the western side of this open section, and at the eastern end there will be a cinema of tubular steel construction, with seating capacity for 120 people, in which the S. & L. films, " Job 99—Pluto " " Thro. the Mill," and " The Tube Age," will be shown thrice daily throughout the run of the Fair.

In additon to being one of the largest manufacturers in the country of Gas List tubes and fittings, WELLINGTON TUBE WORKS, LTD. (exhibiting on Stand C.300), specialise in developing the utilisation of tubes far beyond the orthodox uses for conveying gases and liquids.

Displayed on their Stand are a selection of tubes, fittings and tubulars, as well as a number of products incorporating tubular construction. There are also photographs of the Fabricated Tubular Shedding which was recently supplied for use at the Royal Agricultural Society's Annual Shows. Examples are also shown of fabricated flanged pipework for pressure purposes, and also panels specially designed for panel heating.

An important part of the display is a series of "Weldex" Heaters of capacities ranging from a small Unit to a heavy-duty Plenum, including a gas-fired air heater and an entirely new range of convectors.

The Spiral Tube and Components Co., Ltd., will exhibit, on Stand D.710, a representative range of the well known Spiral Tube heat transmission equipment. including unit heaters to operate from steam, hot water and electricity.

Wire

Wire in various shapes, sizes and materials plays an important part in mechanical and electrical engineering, especially the latter. Reference has already been made in the section on copper and copper alloys to Messrs. Thomas Bolton & Sons, Ltd. On the electrical side, The London Electric Wire Company and Smiths, Ltd., and its associated companies, presents an interesting display of plain, covered and special wires on Stand C.320. The principal features of the parent company's exhibit will include a demonstration of a high speed winding machine; a display of Lewmex synthetic enamel winding wires, including coloured Lewmex; Lewmex insulated Eureka resistance wire; Lewmex and glass covered conductors and Lewmex strip; and of round wires and strips, including the following coverings:—Lewbestos, Lewcoglass, cotton, silk, paper, standard enamel and combinations of the above. Special emphasis will be laid on 50 S.W.G. enamel. Sectionalised exhibits of asbestos covered and other connecting wires will also be on view.

Frederick Smith and Company's display will include gold and silver clad wire for use in braid and tinsel making and other decorative work; hard and soft copper strip for armature winding; and electrolytic copper wire in all sizes for insulation, power transmission, telephone and television cables, fuse wires, and wire for use in the plating industry.

A full range of insulated wires and cables, with special emphasis on the types of constructions for mining and marine work will comprise the exhibit of The Liverpool Electric Cable Co., Ltd.

In the section of the stand devoted to the products of the Vactite Wire Co., Ltd. will be seen examples of wire in strip in less common materials. These include molybdenum wire and tape; nickel chromium wire and tape, either bright or oxidised for resistance heating; Eureka copper nickel wires and tapes, either bright or oxidised for resistances, thermo couples, compensating leads and heating elements operating below 300° C.; nickel wires, strands and tapes, either normally annealed or in gas freed qualities for corrosion resisting leads or electric lamp and valve components; steel and iron wires for mandrels for lamp filament winding; borated copper clad nickel iron for sealing into glass for lamps and radio valves; Vacsteel wire for sealing in wires for soft soda lime and soft lead glasses; copper clad iron wire used in lamp manufacture; platinum sheathed nickel iron wire for dental purposes; and gold clad copper clad nickel iron wire for radio valve grids.

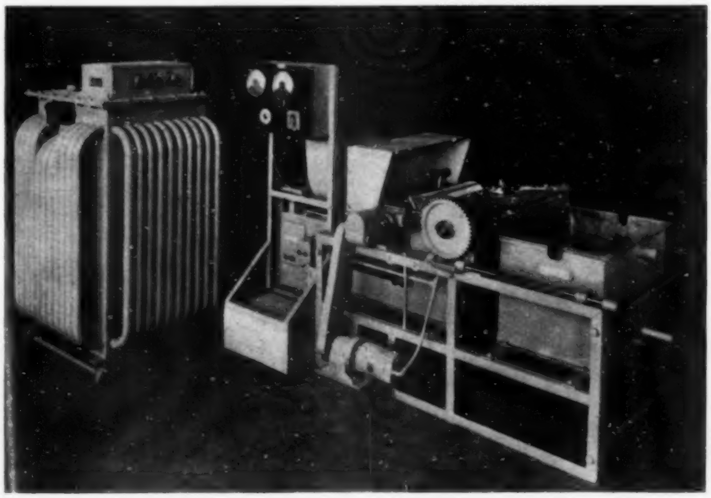
Richard Johnson & Nephew, Ltd. on Stands B.417 and 318, will show exhibits of copper and cadmium copper wires and a wide range of agricultural wires.

The usual extensive range of different qualities and finishes of wire will be displayed on Stand D.607 by John Rigby & Sons, Ltd., particular attention being given to precision drawn pinion rods and special sections

Rylands Bros., Ltd., on Stand A.528 and their associated company The Whitecross Co., Ltd., on Stand A.518 will be exhibiting a wide range of steel wire, and wire products, including bright drawn, annealed coppered, tinned and galvanised wires. Included in the Rylands Bros. exhibit will be examples of their Brylanised wires and nettings. These are zinc coated by the electrolytic process, the company being one of two in this country operating a process in which the electrolyte is obtained direct from zinc ore.

Electroplating

One of the principal exhibits on the Stand (D.203/106) of W. Canning & Co., Ltd., manufacturers of electro-

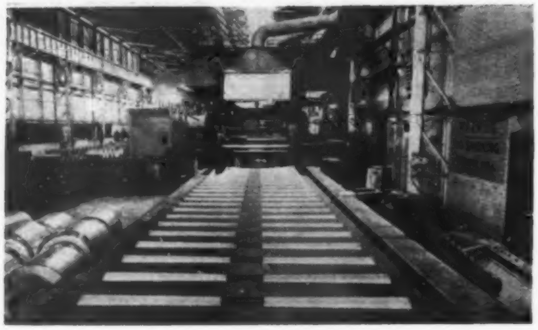


Courtesy of W. Canning and Co., Ltd.

Chromium plating barrel.

Courtesy of Metallisation, Ltd.

Metal spraying torch.



Courtesy of Fescol, Ltd., and The Northern Aluminium Co., Ltd.

Table rollers heavily electroplated to reduce wear and corrosion.

plating equipment, is a new type chrome plating barrel. As will be seen from the illustration, the container is transferred from plating tank to drag-out and, *vice-versa*, for loading and unloading, by hand operated worm and wheel, and an efficient fume exhaust by means of ducting and fan is provided. The barrel is motor driven and the latest type Canning-Westalite rectifier provides the plating current.

Improved "Major" and "Minor" plating barrels, of the octagonal type, suitable for plating small articles in bulk in all solutions other than chrome will also be seen, and an improved electrically heated centrifugal dryer will be in operation to show the rapidity with which small articles can be dried after plating. Other exhibits include a variety of special-purpose polishing machines, general polishing equipment and other miscellaneous requirements of the plating industry.

A tribute to the position which Fescol, Ltd. occupy in the field of engineering electro-plating is evident in the widespread adoption of the term "Fescolise" to mean the electrodeposition of a heavy metallic coating to withstand wear or to build up worn parts. On Stand D.742, many examples may be seen of this type of work including repaired worn crankshafts, a Morgoil bearing coated with chromium on the frictional surface to withstand wear and a pair of planishing rolls on which chromium has been deposited in order that, when polished, large quantities of highly finished non-ferrous metal sheets may be produced thereby.

One of the most interesting examples of the important part being played by the company in the re-equipment of industry concerns the treatment of the table rollers of the Northern Aluminium Co's hot mill at Rogerstone by the Fescol process. It was found that the rollers became scored and corroded in service and after tests had been made to determine the best treatment the process was applied to the existing rollers and also to the rollers of a new mill under construction by Messrs. W. H. A. Robertson & Co., Ltd. The train of rolls is illustrated in the accompanying photograph.

There will also be a number of medium and small components, coated in chromium and nickel, on show to illustrate the variety of work carried out by the company.

Samples plated, using the Efco-Udylite bright nickel process will be displayed on Stand C.611 by the Electro-Chemical Engineering Co., Ltd. Two solutions are available, one for steel and brass, and the other, with a higher chloride concentration and possessing greater tolerance for zinc and copper contamination, for zinc-base diecastings. Also displayed will be an improved pump and filter unit for use with such solutions and equipment for the continuous plating of small parts, such as screws, nuts and washers which are conveyed through a hollow drum by means of an internal screw thread. The drum is constructed of rubber and provided with cathode contacts and internal anodes. Continuous re-circulation of the electrolyte is employed, and the rate of throughput is variable to allow for different times of plating for various processes.

Metal Spraying

Recently installed at the Dudley Works of Metallisation, Ltd. is a metal spraying machine capable of handling rolled steel joists, angles, channels, etc., up to 50 ft. in length. It is the first of its kind and emphasizes the lead which this country has in metal spraying. Details and information concerning the plant will be available on Stand D.326. Metal spraying plant and equipment will also be displayed and demonstrations of the Mark 16 pistol, which is now well established and appreciated in almost every trade, will be given using aluminium, steel, zinc and any other metal drawn into wire form.

Equipment for spraying metal and plastics by the powder process will be exhibited on Stand D.524 by Schori Metallising Process, Ltd. Shot-blasting and dust-collection equipment; spray booths; air-filters; vibratory sieves; thickness meters; and other accessories will be included.

As examples of sprayed metal objects will be displayed steelwork sprayed with zinc for corrosion protection; exhaust silencers, firebars, etc., sprayed with aluminium to prevent scaling; food vessels coated with tin; and worn shafts built up with various metals. On the plastics side, will be shown sprayed polythene and thiokol for protection against chemical attack, together with various examples of decorative finishes and shellac, cellulose acetate, butyrate and similar coatings. With this method of spraying plastics, no solvents are needed.

Sherardizing and Calorizing

Turning to yet another method of metal coating, by heating in a metal powder, the Zinc Alloy Rust-Proofing Co., Ltd. on Stand B.720 will be showing specimens of architectural, engineering, electrical, building and domestic ironwork, rust-proofed by sherardizing. The stand forms a technical information bureau where visitors will be able to obtain full particulars of the process, its cost, and details of the uses to which it can be put in the various trades mentioned. Zinc Alloy Rust-Proofing Co., Ltd. specialise in carrying out the sherardizing operation for the makers of such items as steel casements, metal trim, electrical conduit, iron door furniture, screws, nails, gate fittings, etc.

Sherardized products will be on view on many of the stands at the Fair.

A similar process, in which aluminium powder is used instead of zinc, is calorizing. The virtue of this treatment is the high degree of heat resistance conferred on steel parts thereby, and on Stand D.407 and 306, The Calorizing Corporation of Great Britain are exhibiting samples of calorized solid pressed steel heat treatment containers for cyanide, salt, and lead baths; case-hardening boxes; pyrometer sheaths; and air-heater tubes. Also on view will be Calmet heat resisting alloy steel superheater supports.

Continued on page 55.

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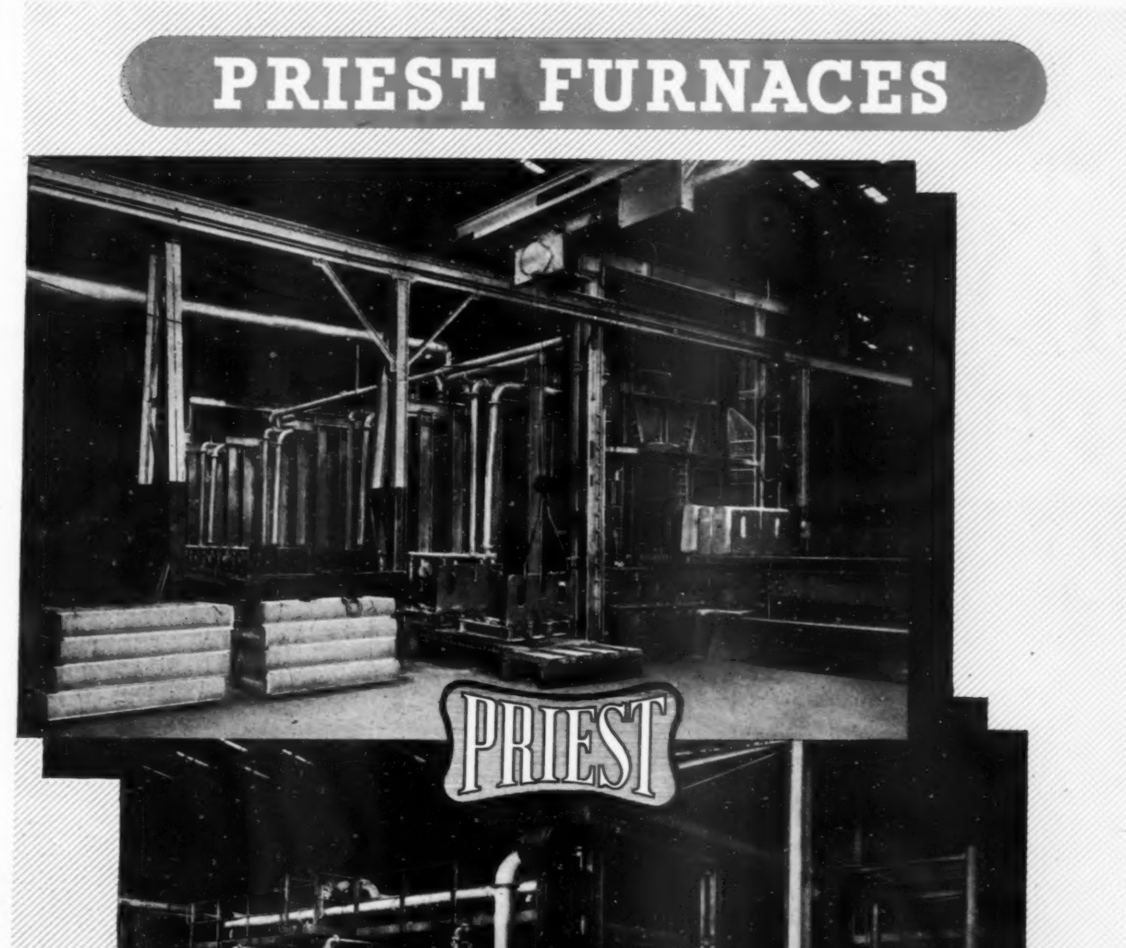
PRIEST FURNACES
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Charge and discharge ends of Priest Pusher type re-circulating furnace with special loading and discharging machines installed at the Falkirk Rolling Mills of The British Aluminium Co. Ltd.
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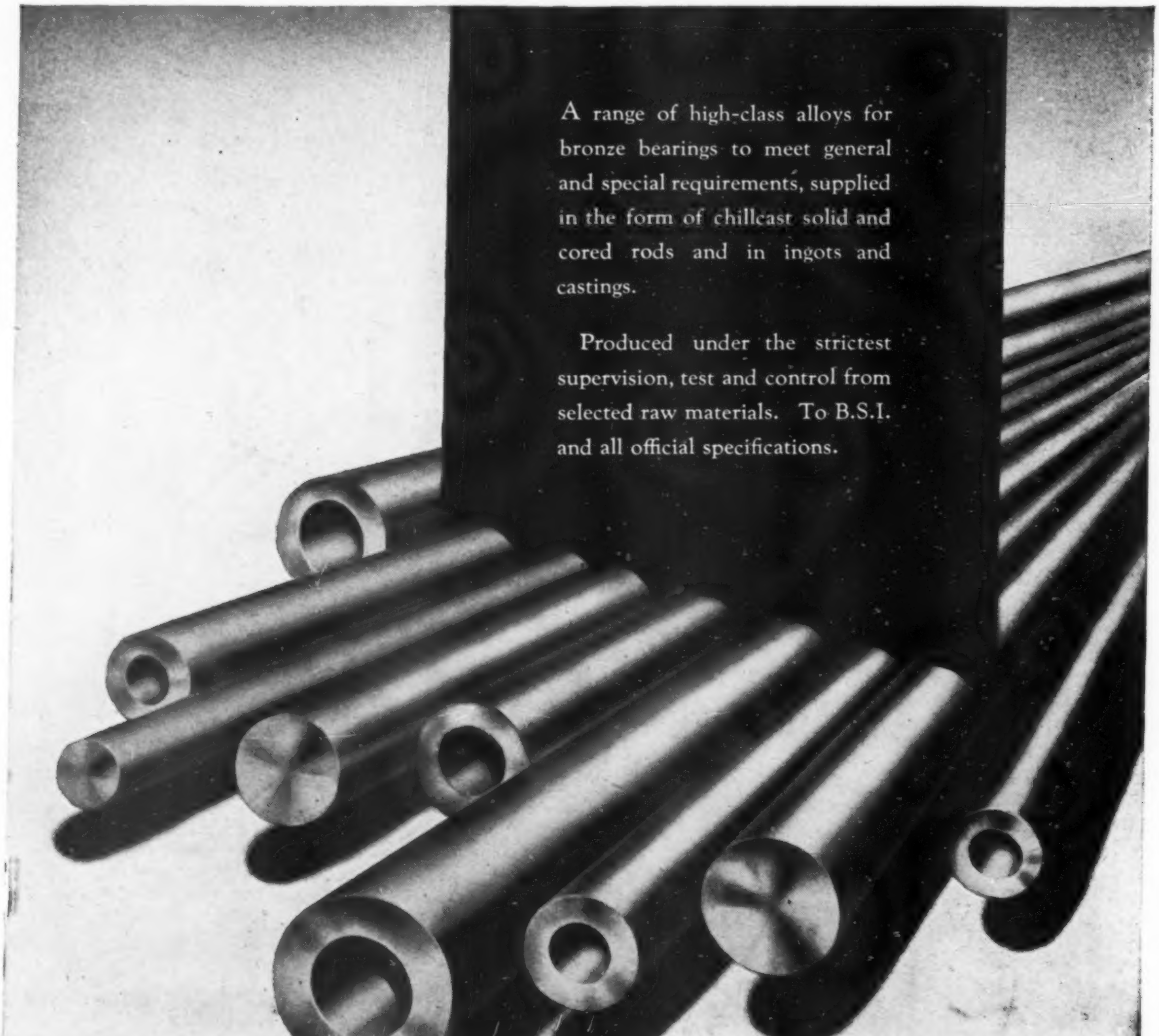

THE MANGANESE BRONZE & BRASS CO. LTD
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Oil Fired Car Bottom Furnace
16′–6″ wide, 16′–6″ high × 27′–6″ long

These two Stress Relieving Furnaces show the versatility of "Dowson & Mason" designs. Large or small Furnaces can be supplied of the Oven, Car Bottom, Removable Roof and Portable Cover types. Designs are available for Town's Gas, Oil Fuel, Producer Gas or Coal Fired Furnaces.

Oil Fired Oven Furnace
3′–6″ wide × 4′–0″ high × 4′–6″ long

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Casehardening Steels in Cyanide-Containing Salt Baths

By F. D. Waterfall, F.I.M.

Chief Metallurgist, Heat Treatment Section, General Chemicals Division, I.C.I. Ltd.

The speed and low cost of the cyanide process, coupled with the cleanliness and wear resistance of the hardened surface produced, makes the method particularly suitable to production heat treatment wherever the service requirements of the components permit the use of case depths up to 0·025 in. Accelerated cyanide baths have been developed which produce case depths up to 0·09 in. Both types are described by the author who clarifies the useful range of each.

ALTHOUGH salt baths have been used to case-harden steels for many years, a measure of uncertainty still exists regarding the range of work capable of being satisfactorily treated in salt baths, and it seems opportune to discuss the cyanide-containing salt baths and their possibilities for casehardening steels. It is proposed to deal with the subject under two main headings :—

(*a*) plain cyanide/carbonate or cyanide/carbonate/chloride baths.

(*b*) Accelerated cyanide baths for deeper cases than those applied in baths (*a*).

Cyanide Baths

The essential constituent of such baths, is, of course, sodium cyanide. They also contain sodium carbonate and sodium cyanate, with or without an alkali chloride (such as sodium chloride) as a diluent.

The cyanide content of the bath is normally maintained at 20–50% sodium cyanide (NaCN). Sodium cyanate (NaCNO) is formed by oxidation of the sodium cyanide during normal working. At operating temperatures of 760–950°C., employing baths covered with a layer of graphite, the percentage of sodium cyanate does not normally exceed 3%. Sodium carbonate is the product finally formed when molten sodium cyanide is exposed to the oxidising action of air. In the simplest terms, therefore, sodium cyanide is oxidised to sodium carbonate in the following procedure :—

(1) Oxygen is picked up by the sodium cyanide from the atmosphere above the bath. This oxygen combines with the sodium cyanide to form sodium cyanate, as follows :

$$2NaCN + O_2 \longrightarrow 2NaCNO$$

(2) Sodium cyanate decomposes thermally to give sodium cyanide, sodium carbonate, carbon monoxide and nitrogen thus :—

$$4NaCNO \longrightarrow 2NaCN + Na_2CO_3 + CO + 2N$$

The cyanide reformed from the cyanate is available for further reaction, but the sodium carbonate is, of course, the end product.

The carbon monoxide liberated during the decomposition of the cyanate yields carbon when in contact with the steel immersed in the bath. The carbon is absorbed by the steel, entering, at the carburising temperature, directly into the gamma iron lattice.

For convenience, however, the reaction is written thus :—

$$3Fe + 2CO \longrightarrow Fe_3C + CO_2$$

Some of the nitrogen liberated by breakdown of sodium cyanate is also taken into solution, at the carburising temperature, by the gamma iron.

Since sodium carbonate is the end product of the carburising reaction it tends to build up in the cyanide bath and may be present up to 80% of the bath composition.

The composition of a working cyanide/carbonate bath is usually :

Sodium cyanide	20–50%.
Sodium cyanate	0·5–3·0%.
Sodium carbonate	Balance.

Additionally baths may contain an alkali chloride, but this is a diluent and does not enter into the carburising reaction.

For economic reasons it is usual to keep a layer of graphitic carbon on the bath surface to prevent an undue degree of oxidation of the cyanide to carbonate, this graphite also serving to prevent fuming of the bath.

Obviously if satisfactory results are to be achieved conversion of the whole of the bath contents to sodium carbonate must be avoided. It is, however, frequently found that, in production working, simple topping up of a cyanide bath with 96/98% sodium cyanide, to replace salt lost as 'drag-out' on parts being treated, is sufficient to maintain a minimum of 20% sodium cyanide in the bath. In other cases it is necessary to bale out a little of the melt and replace it with 96/98% sodium cyanide.

Depths of Cases Applied in Cyanide Baths

Generally speaking case depths greater than 0·025 in. are not applied in ordinary cyanide baths. (Accelerated cyanide baths, to be mentioned later, are, however, in regular use for applying cases of depths up to 0·09in.).

In point of fact, however, relatively deep cases can, if necessary, be applied in cyanide baths, as can be seen from the curves in the now well-known Fig. 1. When applying such depths of case it is normal to use baths containing 40–50% sodium cyanide, rather than baths of cyanide content at the lower end of the 20–50% sodium cyanide range already mentioned. It is for surface hardening, or applying case depths up to 0·01 in. that bath compositions of 20–30% sodium cyanide are commonly employed.

Microstructure of the Case Produced in Cyanide

Figs. 2–5 show the microstructures of mild steel test pieces carburised in cyanide/carbonate baths of gradually increasing cyanide contents. From these, two

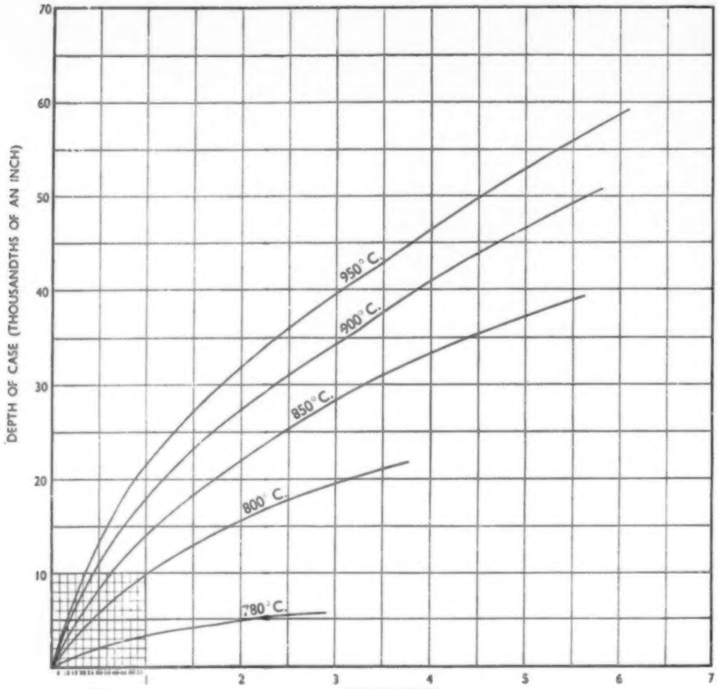


Fig. 1.—Time-penetration curves showing total case depths obtained in cyanide baths containing 40/50% sodium cyanide. (Mild steel specimens slowly cooled after carburising.)

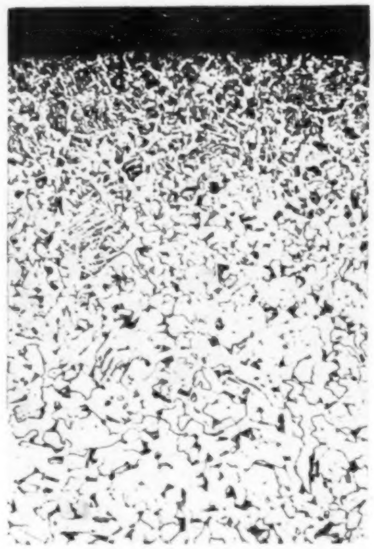


Fig. 2.—Mild steel carburised 1-hour at 900° C. in a cyanide-carbonate bath containing 10% sodium cyanide. Air cooled. Etched in 2% Nital. × 100.

things will be observed : (*a*) The cases, particularly at the lower end of the cyanide range, are not of eutectoid composition ; (*b*) The transition from case to core is very gradual, thus avoiding the danger of exfoliation in hardened cases. (As will be explained later this rather extended transition zone is a disadvantage where work has to be ground.)

Figs. 6–8 show the microstructures of cases produced in cyanide/carbonate baths analysing 40 – 44 % sodium cyanide. The carburising time was 1 hour at the temperatures of 950° C., 900° C., and 850° C., respectively. Microstructures corresponding to Figs. 6–8, but after hardening, that is reheating to 780° C. and water quenching, are shown in Figs. 9–11.

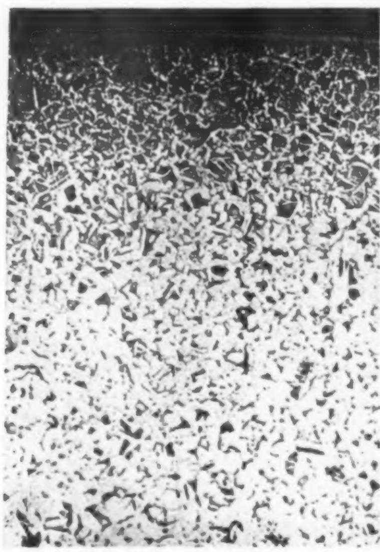


Fig. 3.—Mild steel carburised 1-hour at 900° C. in a cyanide-carbonate bath containing 20% sodium cyanide. Air cooled. Etched in 2% Nital. ×100.

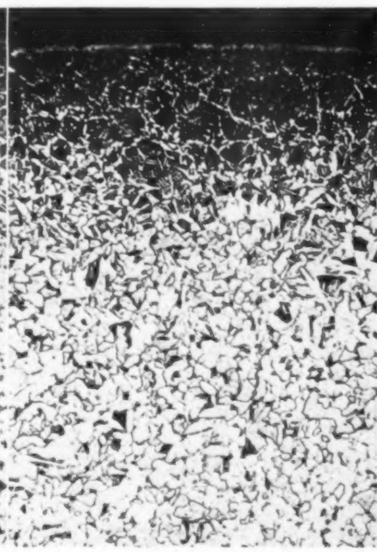


Fig. 4.—Mild steel carburised 1-hour at 900° C. in a cyanide-carbonate bath containing 30% sodium cyanide. Air cooled. Etched in 2% Nital. ×100.

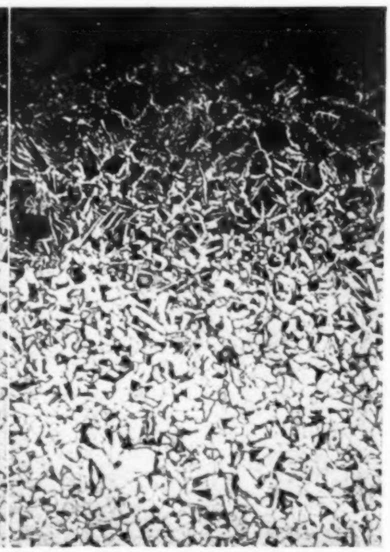


Fig. 5.—Mild steel carburised 1-hour at 900° C. in a cyanide-carbonate bath containing 37% sodium cyanide. Air cooled. Etched in 2% Nital. ×100.

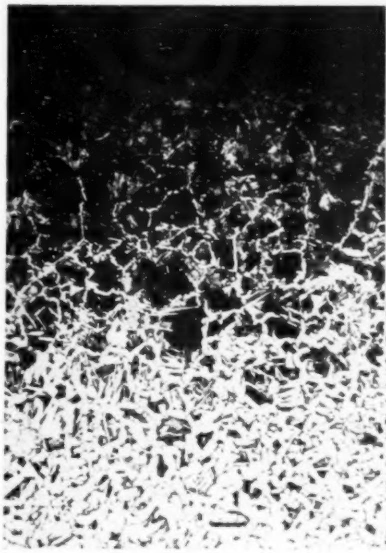


Fig. 6.—Mild steel carburised 1-hour at 950° C. in a cyanide-carbonate bath containing 42% sodium cyanide. Air cooled. Etched in 2% Nital. ×100.

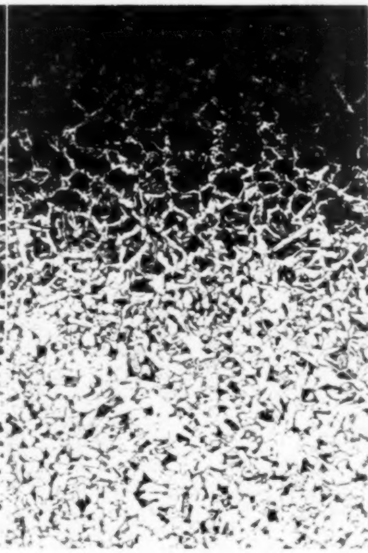


Fig. 7.—Mild steel carburised 1-hour at 900° C. in a cyanide-carbonate bath containing 44% sodium cyanide. Air cooled. Etched in 2% Nital. ×100.

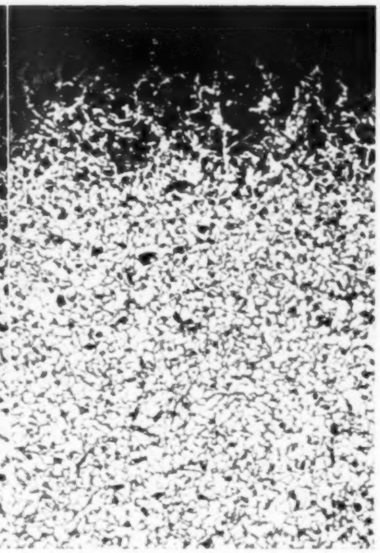


Fig. 8.—Mild steel carburised 1-hour at 850° C. in a cyanide-carbonate bath containing 40% sodium cyanide. Air cooled. Etched in 2% Nital. ×100.

Hardness of the Case Produced on Mild Steels in Cyanide and the Effect of Bath Strength

This question deserves some little space since at times conflicting statements are made as to the hardness of the case on parts treated in cyanide. If we confine our attention for the present to mild steel parts treated in the bath, a few typical examples as to hardness might be of value.

Consider first the upper end of the working range for the cyanide baths and test pieces carburised for 1, 2 and 4 hours at 950° C., and 1 and 2 hours at 900° C. and 850° C., respectively, oil quenched, then reheated to 780° C. and water quenched. Depth hardness curves are

Fig. 9.—Mild steel carburised 1-hour at 950° C. in a cyanide-carbonate bath containing 42% sodium-cyanide. Oil quenched. Reheated to 780° C., water quenched. Etched in 2% Nital. ×100.

Fig. 10.—Mild steel carburised 1-hour at 900° C. in a cyanide-carbonate bath containing 44% sodium cyanide. Oil quenched. Reheated to 780° C., water quenched. Etched in 2% Nital. ×100.

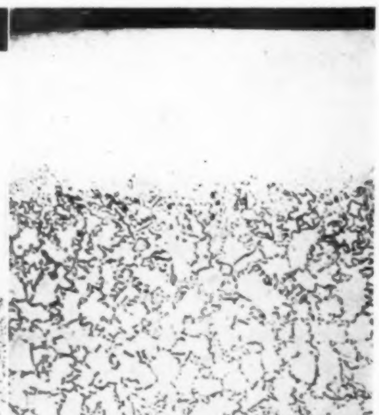
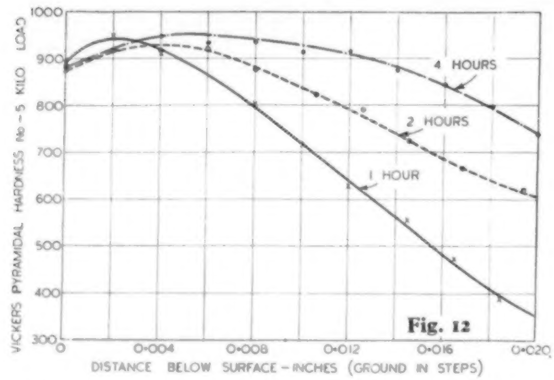
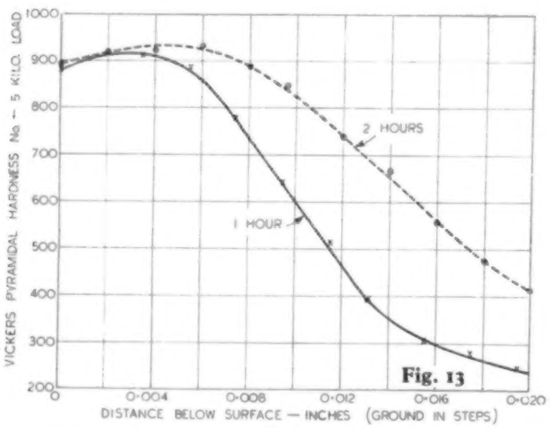


Fig. 11.—Mild steel carburised 1-hour at 850° C. in a cyanide-carbonate bath containing 40% sodium cyanide. Oil quenched. Reheated to 780° C., water quenched. Etched in 2% Nital. ×100.





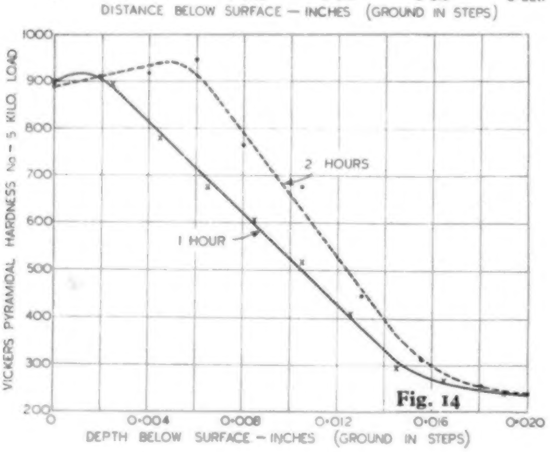


Fig. 12.—Depth-hardness curves for 9/16 in. diameter mild steel bars carburised in a 40% sodium cyanide bath at 950° C. and oil quenched. Reheated to 780° C. and water quenched. (Ground in steps).

Fig. 13.—Depth-hardness curves for 9/16 in. diameter mild steel bars carburised in a 43% sodium cyanide bath at 900° C. and oil quenched. Reheated to 780° C. and water quenched. (Ground in steps.)

Fig. 14.—Depth-hardness curves for 9/16 in. diameter mild steel bars carburised in a 40% sodium cyanide bath at 850° C. and oil quenched. Reheated to 780° C. and water quenched. (Ground in steps.)

shown in Figs. 12–14. From these curves three points will be noticed:

(*a*) The hardness of a hardened 'cyanide' case is not excessively high being about that obtained by good packhardening practice.

(*b*) The immediate surface layers are slightly softer than the underlying regions. (This is due to the effect of nitrogen at the surface, producing some retained austenite on quenching.)

(*c*) The transition from the glass-hard part of the case to the hardness of the core is quite gradual.

Consider now the hardness of shallower cases conferred to mild steel in cyanide and the effect of varying the cyanide percentage in the bath. For the sake of simplicity, attention will be confined to an operating temperature of 900° C. The surface hardness obtained on mild steel test pieces treated at differing bath strengths for 10 and 30-minutes, respectively, can be seen from Figs. 15 and 16. These figures indicate that surface hardnesses on water quenched mild steel are good, *i.e.*, 850–900 V.P.N., even when relatively low percentages of cyanide (down to 16% NaCN) are present in the bath. The effect of lowering the bath strength makes itself more apparent, however, on the oil quenched specimens. When a minimum surface hardness of say V.P.N. 750, on thin mild steel pieces which are oil quenched, is required, a cyanide content of 25% NaCN minimum, coupled with a soaking time of say 30-minutes, should be employed. Size of section has, in mild steel, a very important bearing on the ability of the piece to harden with an oil quench. The above remarks as to oil quenching only apply, therefore, to thin sections of mild steel.

Hardness of the Cases Produced on Alloy Steels in Cyanide and the Effect of Bath Strength

It is a well established practice to surface harden medium carbon alloy steels of the chromium or nickel-chromium type in cyanide baths to confer an increased surface hardness over that obtainable by hardening the steel without the use of cyanide. For example, automobile, truck, or tractor gears are frequently treated in cyanide.

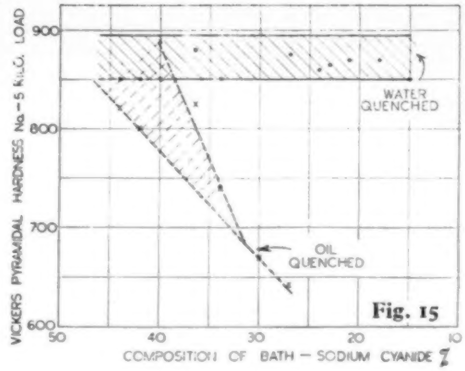
Consider the example of the nickel-chromium steel En.24, containing carbon 0·35/0·45%, nickel 1·30/1·80%, chromium 0·90/1·40%, molybdenum 0·20/35%. This material, as hardened by oil quenching, normally has a hardness of V.P.N. 525–575. The surface hardnesses of such steels are raised to V.P.N. 700/800 by cyanide treatment, but the increase in wear resistance certainly exceeds this proportionate increase in hardness.

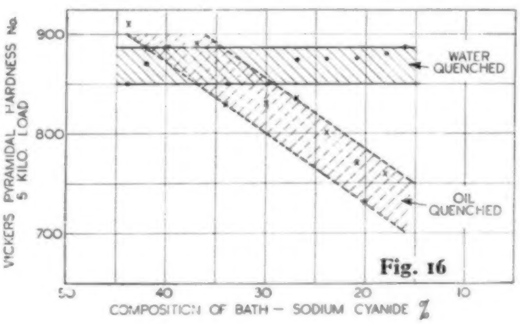
The effect of varying the cyanide content of the cyanide bath used for treating such steel has been studied and results on En.24 may be of interest. If we confine our remarks to a soaking time of 45-minutes in cyanide at 800°/810° C., it can be said that bath strengths as low as 20% sodium cyanide, give surface hardnesses little inferior to those obtained in a 40–45% sodium cyanide bath, all hardnesses lying in the range V.P.N. 700–800.

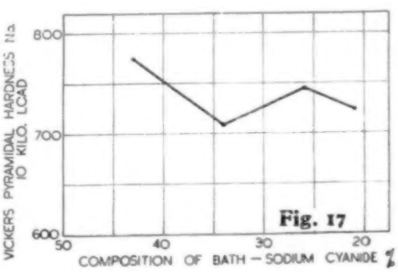
Fig. 17 indicates, graphically, average surface hardnesses obtained on En.24 in the differing bath strengths mentioned.

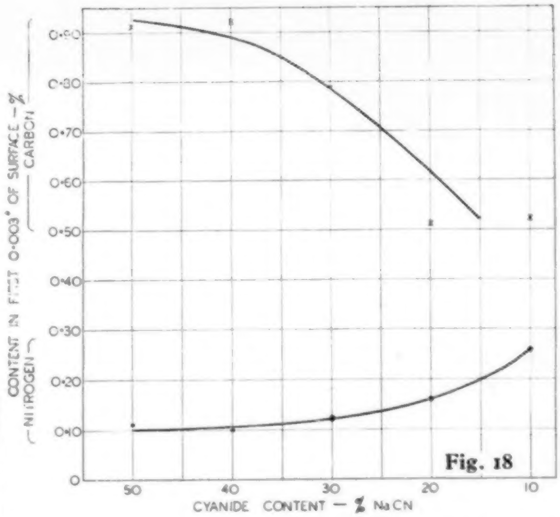
The Composition of the Case Produced in Cyanide

Charred bones and burnt leather are now rarely used for pack hardening. They have been replaced, for economic reasons, by activated charcoal compounds. It is,









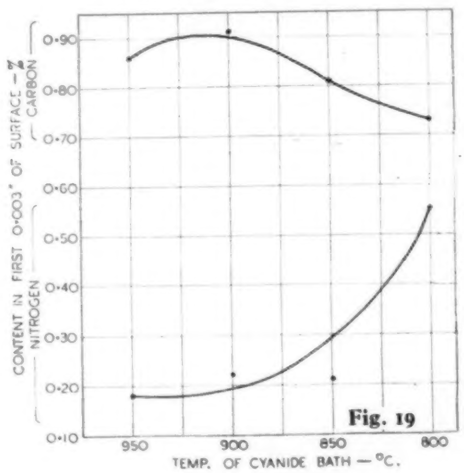


Fig. 15.—The effect of bath strength on surface hardnesses of test pieces treated in a cyanide-carbonate bath. ¾-in. diameter mild steel test pieces (En. 32). Treated for 10-minutes at 900° C. and water or oil quenched (Bands indicate hardness range).

Fig. 16.—The effect of bath strength on surface hardnesses of test pieces treated in a cyanide-carbonate bath. ¾-in. diameter mild steel test pieces (En. 32). Treated for 30-minutes at 900° C. and quenched in water or oil. (Bands indicate hardness range.)

Fig. 17.—The effect of cyanide bath strength on surface hardnesses of nickel chromium steel (En. 24). Test pieces treated for 45-minutes at 800/810° C., followed by an oil quench.

Steel Analysis	Range
Carbon	0·35/0·45%
Nickel	1·3/1·8%
Chromium	0·9/1·4%
Molybdenum	0·2-0·35%

however, of interest to remark that carbon cases conferred to steel by bone or leather mixtures quite often contained nitrogen as well as carbon in the case, in this respect having something in common with the cyanide bath, which also confers these two elements to steel

Fig. 18.—The effect of cyanide percentage on the composition of the case produced in a cyanide bath at 950° C. mild steel test pieces (2S14) carburised for 2½-hours at 950° C. The bath was covered with a layer of graphite.

Fig. 19.—The effect of temperature of carburising on the composition of the case produced in a cyanide carbonate bath containing approximately 50% sodium cyanide. Mild steel test pieces (2S14) carburised for 2½-hours at the temperature stated. The bath was covered with a layer of graphite.

processed in it. (Activated charcoal compounds confer carbon only.)

The actual amount of carbon and nitrogen in the cyanide case will depend on three factors :

(1) The bath strength.
(2) The temperature of the bath.
(3) The thickness of the carbonaceous covering used on the bath.

The composition of a case applied in a 40–50% sodium cyanide bath is predominantly carbon with a small amount of nitrogen. As the bath strength is lowered to say 10% sodium cyanide so the carbon content of the case falls whilst the nitrogen content increases. This is readily observed by reference to Fig. 18.

Fig. 20.—Austenite, plus martensite, in the case of a 5% nickel casehardening steel. (Hardness of case Rockwell C.51/52). Etched in 2% Nital. × 2,000.

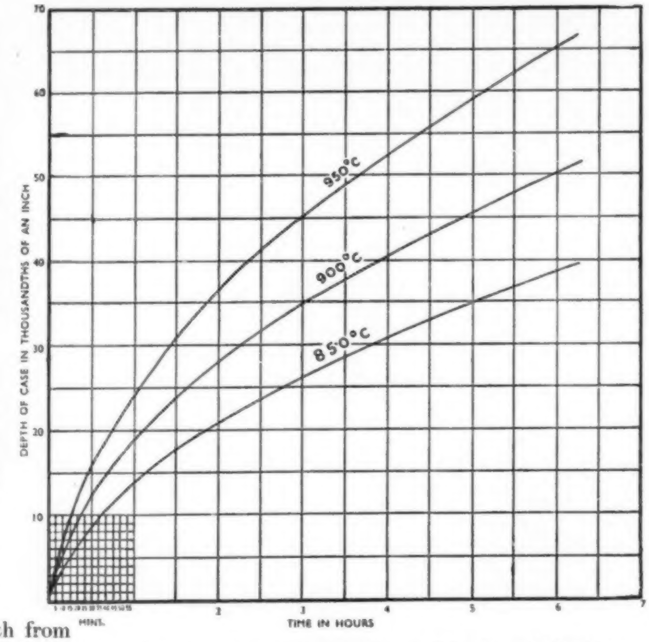


Fig. 22.—Time-penetration curves for mild steel carburised in accelerated cyanide baths (Rapideep "S" and Rapideep "H").

Lowering the temperature of the cyanide bath from 950° to 800° C. results in a drop in carbon and increase in nitrogen percentage in the case. This can be observed by reference to Fig. 19 showing results obtained on a 50% cyanide bath.

Increasing the thickness of the graphitic covering on a cyanide bath will, other things being equal, tend to increase the carbon and lower the nitrogen in the case produced.

The Characteristics of a Cyanide Hardened Case

It is reasonable to enquire what influence the above mentioned nitrogen has on the characteristics of the case produced. Some writers have stated that the case produced in cyanide is extremely hard and brittle and explain the effect as due to hard and brittle iron nitrides. We have already shown that hardnesses obtained on case hardening steels are those normally expected by good packhardening practice. Moreover it is well known that iron nitrides are not particularly hard if compared with the hardnesses of a 0·9% carbon martensite. (An unalloyed steel nitrided in ammonia contains an abundance of iron nitrides but it certainly is insufficiently hard to be satisfactorily wear-resistant.) The writer has not yet seen iron nitrides in the hardened case of a part carburised in cyanide. What then is the effect of nitrogen? When casehardening steels in cyanide, the bath and steel are at a temperature above or within the

Fig. 21.—The same case as shown in Fig. 20 after 15-minutes at -76°C. in a "Drikold" bath. (Note the much reduced amount of austenite.) Hardness now Rockwell C.59/61. Etched in 2% Nital. × 2,000.

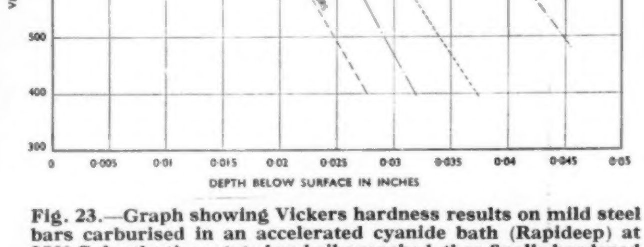


Fig. 23.—Graph showing Vickers hardness results on mild steel bars carburised in an accelerated cyanide bath (Rapideep) at 950° C. for the time stated and oil quenched, then finally hardened with a water quench from 780° C. (Bars ground in steps.)

critical range of the steel, the carbon and nitrogen both enter into solution in the gamma iron present at those temperatures. If quenching is sufficiently rapid both carbon and nitrogen are retained in super-saturated solid solution as ' martensite '. In this respect, therefore, carbon and nitrogen have a similar effect. Nitrogen in solution has also an effect somewhat similar to alloys like nickel, molybdenum, etc., in that it lowers the critical cooling speed required for effective hardening and indeed it gives a tendency for austenite retention on quenching. Generally speaking austenite retention in a cyanide hardened case is not serious enough to produce hardnesses below the required minimum, although occasionally a combination of alloy in the steel, and cyanide treatment may result in a rather soft austenitic surface. This condition when met is easily overcome by continuing the cooling process for the parts in question, as for instance by using a refrigerator or more simply by immersing them in a " Drikold " bath. (The " Drikold " bath is prepared by adding " Drikold "—solid carbon dioxide—to a bath of methylated spirit or white spirit held in a well-lagged container. Whilst the photomicrographs, Figs. 20 and 21, were not on parts treated in cyanide, they will serve to illustrate the effect of sub-zero cooling to reduce the retained austenite in the case on a 5% nickel case-hardening steel. Note that by simply sub-zero cooling to –76° C. the casehardness has risen by as much as nine Rockwell " C " points.

Wear Resistance of a Cyanide Hardened Case

To return for a moment to this question of the wear resistance of the cyanide case :—

Wear tests have repeatedly confirmed that a case produced by cyanide treatment has a greater resistance to wear than a case of equivalent hardness conferred by pack or gas carburising methods. It is reasonable to ask why this should be if hardnesses are the same ? The explanation has been found in the resistance of martensite, rich in nitrogen, to softening on heating. During frictional loading heat is, of course, developed, even when the surfaces are lubricated. This heat results in softening and sometimes scoring of the contacting surfaces. Whilst cyanide hardened parts do, of course, soften under heat they do so at a slower rate than parts which have a hardened " pure carbon " case. By way of illustration 1·2% carbon steel wires were hardened in cyanide and afterwards tempered at 450° C. The surface hardness as hardened was slightly lower than that of the material underneath. After tempering at 450° C., however, the surface was found to be harder than the underlying regions, as can be seen from Table I, comparing the Vickers hardnesses obtained with 5 and 30-kilo loads.

TABLE I.

1·2% Carbon Steel Wire. Given 1-hour at 800° C. in 46% Sodium Cyanide and oil quenched. Tempered 1- hour at 450° C.

	Vickers Hardness 5-kilo load	Vickers Hardness 30-kilo load
Before Tempering	776	837
After Tempering	605	554

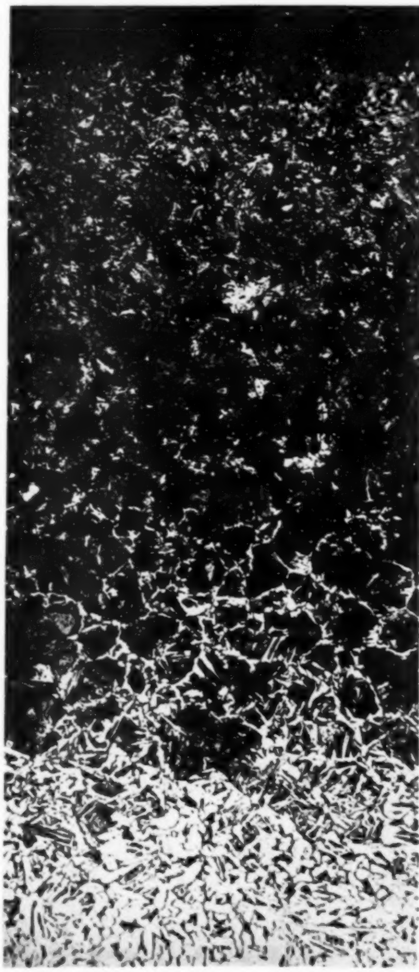


Fig. 24.—Mild steel carburised for 4-hours in accelerated cyanide bath (Rapideep) at 950° C., and slowly cooled. Etched in 2% Nital. × 100

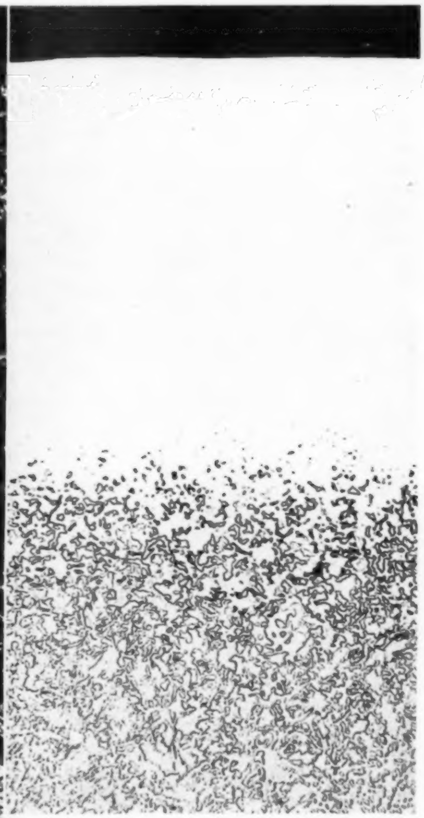


Fig. 25.—Mild steel carburised for 2-hours in accelerated cyanide bath (Rapideep) at 950° C., and air cooled.

Reheated to 900° C. and water quenched.

Reheated to 780° C. and water quenched.

Etched in 2% Nital. × 100.

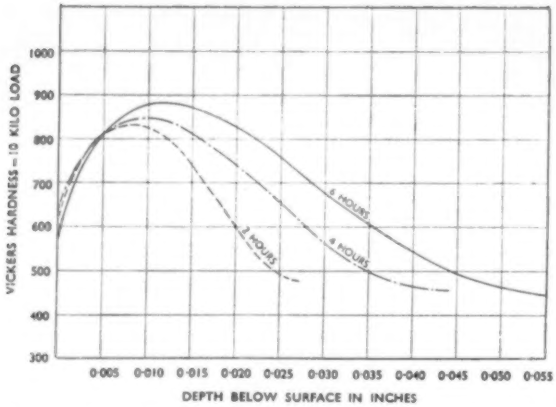


Fig. 26.—Nickel chromium steel (B.S. En. 39) carburised in accelerated cyanide bath (Rapideep "H") for 2-4- and 6-hours respectively at 900° C. Reheated to 770° C. and oil quenched. (Ground in steps).

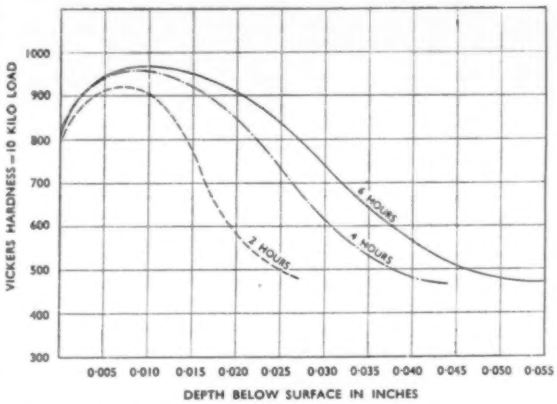


Fig. 27.—Same specimens as Fig. 26, which were carburised in accelerated cyanide bath (Rapideep "H") for 2-4- and 6-hours respectively at 900° C. Reheated to 770° C. and oil quenched, then immersed in a bath cooled to –76°C. with "Drikold" (solid carbon dioxide). (Bars ground in steps.)

Microsections showed the effect even more strikingly than the hardness tests, 0·001 in. at the surface of the tempered rings still remaining predominantly martensitic.

ACCELERATED CYANIDE BATHS

The main limitation of the cyanide method when in competition with established packhardening practices was the fact that for a given case depth to be applied the pack hardened piece had a greater depth of glass-hard zone than did an equivalent depth of case produced in the cyanide-carbonate bath. For instance on a case of 0·04 in. total depth in good packhardening practice the "glass-hard" zone of the case, after quenching, would be 0·02 in., whereas the case obtained in a 40% cyanide/carbonate bath, although of equivalent total depth of 0·04 in. had only a glass-hard zone one-third of the total depth (i.e., approximately 0·013 in.) with a transition zone of approximately 0·027 in. This meant that the cyanide hardened part allowed less latitude in grinding if a satisfactory amount of the hard part of the case was to be left after this operation.

As a result of research conducted, accelerated cyanide baths were developed employing basically the alkaline earth chlorides, plus cyanide, and these have now been employed in industry over a period of years, applying case depths of 0·02–0·09in. total. Of these depths at least one-half is glass-hard, thereby being equivalent to good pack hardening practice. The case produced in an accelerated cyanide bath contains predominantly carbon, with but a little nitrogen, as distinct from the mixed carbon-nitrogen case furnished by the straight cyanide bath. For example, a typical case produced on mild steel in, say, I.C.I. Rapideep "H" at 900°–950° C., contains a "eutectoid" zone of 0·90/1·0% carbon, with approximately 0·10% nitrogen at the immediate surface of the case.

(The chemistry of the carburising activity in accelerated cyanide baths is still not fully understood, thus no attempt will be made here to give an outline of the reactions within the salt.)

A given case depth can be applied more rapidly in an accelerated cyanide bath than can be done in production in the pack. For instance, by the salt bath method, 0·03 in. case is applied in 1½-hours at 950° C. with a total carburising cycle of 2-hours, whereas 7–8 hours by the pack method is the more usual cycle time.

Fig. 22 shows time-penetration curves for such an accelerated cyanide bath and Fig. 23, depth hardness curves obtained on mild steel test pieces after quenching.

(*Continued on page* 43)

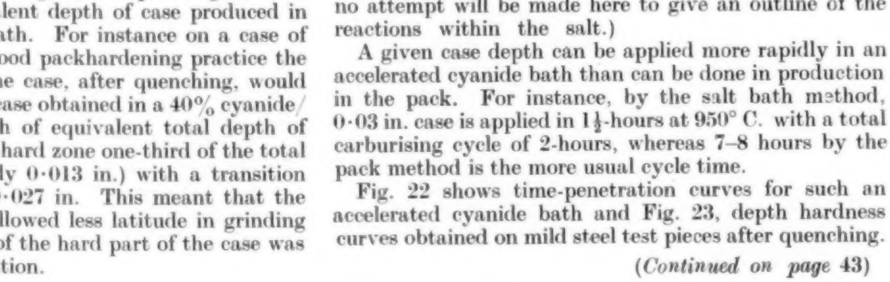


Fig. 28—An installation of salt bath furnaces employing cyanide-carbonate, or accelerated cyanide baths for casehardening purposes.

Some Applications of the High Frequency Induction Heating Process

By J. C. Howard

(Director of the Electric Furnace Co., Ltd.)

Developed originally for the melting of metals, the use of high frequency induction heating for heating solid metal is increasing rapidly. Following on the development of the Tocco process for surface hardening, induction heating is now being applied to the usual heat treatment processes, such as normalising and hardening and tempering; to, the heating of billets for forging; and to brazing and soldering operations. In this article the author covers the field of "solid heating" from the practical aspect, outlining the principles involved and the equipment used.

THE first use of the principle of electric induction was Michael Faraday's experiment, in 1831, in which two coils of wire were wound round an iron ring. This was the first electric transformer and induction heating apparatus can be likened to a transformer where the inductor is the primary and the workpiece the secondary. Current is made to flow in the workpiece which is heated up by its own resistance to the flow of the induced electric current. With magnetic material, there is also additional heat provided by hysteresis losses. However, heating by hysteresis is of lesser importance and in the case of most steel treatment, where the steel has to be heated above the Curie point, the whole of the heating in the later stage is entirely by I^2R heating. For heating to take place it is essential for the workpiece to be a conductor.

The first uses of the induction heating principle were for the melting of metals. This is a subject on its own and this article is confined to the practical use of this old principle for the heat treatment of metals, for the heating of metals for hot working, and for heating for brazing.

Equipment Used

There are some limited applications using normal frequency power for this work but the most popular equipments to-day employ frequencies ranging from 1,000 cycles to 500,000 cycles.

There are three main forms of high frequency generator—the spark gap oscillator, the valve oscillator and the motor generator. The writer has had extensive experience of the spark gap oscillator for metal melting, finding it most useful for furnaces up to 20 lb. in capacity, but in his view, this generator is not as adaptable as the other two for the processes under review.

Valve equipment is commercially available in sizes up to about 50 kw. output. Much larger units, however, have been built but, because they are expensive and require much space, they are only installed where the nature of the process calls for the special characteristics only obtainable these days with valve units. The operating frequency of valve oscillators depends on circuit design and is usually between 300,000–500,000 cycles.

Motor generators are available in all powers, ranging from about 5 kw.–3,000 kw., and in frequencies ranging from 500–10,000 cycles. The upper power limit at 10,000 cycles is now about 500 kw. but future design improvements may raise that limit if it is found necessary.

It will be noted that over the lower power range both valve and motor generator are available and for many jobs, where frequency is not vital, either can be used with equal satisfaction. In such cases the selection is, therefore, often determined by first cost and for equipments up to about 25 kw., prices ruling to-day in this country are in favour of the valve type.

Some Technical Aspects Affecting Selection of Equipment

It is well known that, due to skin effect, the induced current concentrates in the outer layers of the workpiece. Full advantage is taken of this in the surface hardening of steel when the skin is heated to temperatures above the Curie point. Osborn quotes a very simple formula for calculating the approximate depth of penetration of electrical energy under such conditions. The equation is :—

$$D = \sqrt{\frac{4}{F}}$$

Where D is the depth of penetration in inches.

Where F is the frequency in cycles per second.

The depth of the hardened zone is always in excess of the depth of current penetration because during the heating period, no matter how short, heat is penetrating to lower depths by thermal conduction. To reap any benefit from the higher frequencies in the way of thinner hardened cases, it is essential to have sufficient power concentration to heat up the surface in a very short time and quench out quickly, otherwise heat flow by conduction will nullify any benefit gained.

With valve equipment operating at 300,000 cycles, 0·020 in. is the approximate minimum practical case thickness and for this a power concentration of about 10 kw./inch^2 of surface area hardened would be needed. The actual heating time must be very short, and, to obtain full hardness, the steel structure and analysis should be such as will respond to such rapid heating, permitting complete solution of the carbides before quenching. Valve generators are, therefore, selected when an exceptionally thin case is essential but, due to power limitations with available sizes of valve sets, large areas cannot be so treated by single-shot methods.

For single-shot hardening of areas over 10 square inches, it is usual to employ motor generators. The power concentration depends on the case depth required and the diameter of the material but it is usually between 5 kw. and 10 kw./sq. in. of hardened area.

The relationship between frequency and diameter of workpiece is also important. The higher the frequency the smaller is the diameter which can be heated. The

upper limit of frequency possible with motor generators is about 10,000 cycles and at this frequency, using a circular inductor, $\frac{1}{4}$ in. diameter steel is about the smallest that can be through-heated to hardening temperature, and $\frac{1}{2}$ in. diameter steel is about the smallest that can be surface hardened. For these sizes, however, the high frequency of the valve equipment is, perhaps, more effective and, in any case, would be essential for smaller diameters. Wire of $\frac{1}{8}$ in. diameter is about the thinnest that can be through-heated for hardening with a valve generator, but this diameter cannot be surface hardened.

For surface hardening of stock over $\frac{3}{4}$ in. in diameter, where the output is large, motor generator equipment is usually necessary because of power requirements. For through-heating of stock over $\frac{3}{4}$ in. diameter, either for through-hardening, annealing or heating for forging, the lower frequency range of the motor generator, is preferred because of the greater depth of penetration and usually, in such cases, the power requirements are greater than are practicable with valve equipments.

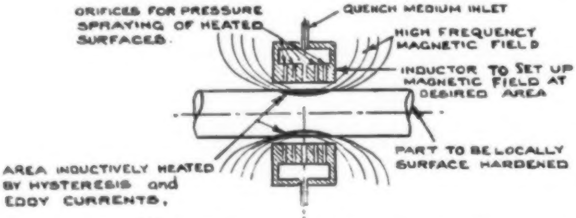


Fig 1.—Schematic diagram of an inductor block for surface hardening a cylindrical section.

The design of inductors is fundamentally the same for all frequencies. In the simplest case of heating cylindrical stock, they can either be single-turn blocks or made from multi-turn tubing, depending on the specific application. Often a high frequency transformer is used to provide power at a voltage suitable for the transformer.

A typical section of a single-turn inductor for surface hardening is shown in Fig. 1. When the power is switched on the surface is heated and the depth of the heated zone is governed by the time of heating, the power concentration and frequency as already explained. The width of the heated area is governed by the width of the inductor.

After the requisite time of heating, the power is switched off and the quench applied. This is usually known as the one-shot method and, for a given case thickness and diameter, the power requirements are roughly proportionate to the area hardened so that twice the area calls for twice the power and so on.

If the stock is progressively fed through the inductor, the heated case follows progressively along the bar and if a spray quench is arranged to quench the steel as it emerges from the inductor, the whole surface can be hardened with much less power than with the one-shot method. This progressive method is adopted for pins, shafting, etc.

If power concentration is low, heat flows by conduction to the inside and the whole section can be evenly heated for through hardening, annealing, tempering, heating for forging, etc. Usually such inductors are multi-turn. The heating can be either single-shot, as may be used for forging a local area, or the heating can be progressive as is used for the continuous hardening and tempering of barstock, or the continuous heating of a stream of slugs or billets for forging.

Some Applications of Surface Hardening

The first practical application of induction heating, other than melting, was the surface hardening of crankshaft journals. This was carried out by the Ohio Crankshaft Company in 1933. The one-shot principle was adopted and the TOCCO process was developed.

The journal to be hardened was surrounded by a split inductor, tailor-made to suit the journal surface and to give the required hardened zone. The inductor had to be split because a solid ring type could not be fitted on account of the proximity of the webs. Fig. 2 shows an arrangement of a typical heater station for heating one journal. A transformer is necessary to step down from the generator voltage to that suitable for the single-turn inductor. The power requirements are pre-set on the control panel and when the station control button is pressed, a controlling timer is set in motion which controls the heating and quenching cycles. The quench water sprays through holes in the inductor directly on to the hot face.

The operation, when repeated on other similar journals, is so consistent that perfect repetition of results is obtained.

There are two types of production unit for crankshaft hardening adopting this principle. First, a tunnel line arrangement along which there are five to seven different heater stations. The crankshaft to be treated is passed on a bogie along the tunnel. The different stations are set up to treat the different journal areas on the shaft. By changing inductors the tunnel line can be set up to treat a wide range of shafts, provided always that the areas to be hardened are within the capacity of the motor generator.

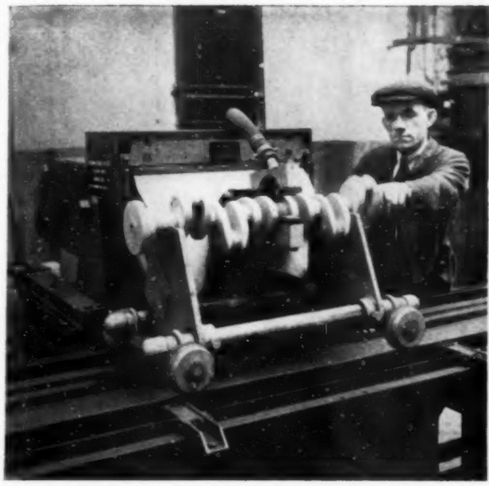
A seven-station tunnel line is capable of treating 12 six-cylinder shafts per hour. Fig 3 shows a typical tunnel line.

For larger production of the lighter shafts, vertical stations are preferred. In each station there are three or four inductors, each with its own transformer, and the inductors are properly spaced so that they can be quickly and automatically clamped around the journal. A sequence timer controls the heating of one journal after the other. The shaft is then transferred to a second station where other journals are treated and afterwards to a third and sometimes a fourth unit. Fig. 4 shows two units of a four-unit vertical installation which has a production of 20–25 six-cylinder shafts per hour.

The one-shot principle is used on a wide variety of parts, such as the cams and journals of camshafts, hardening of steering ball pins and numerous other parts that are hardened locally.

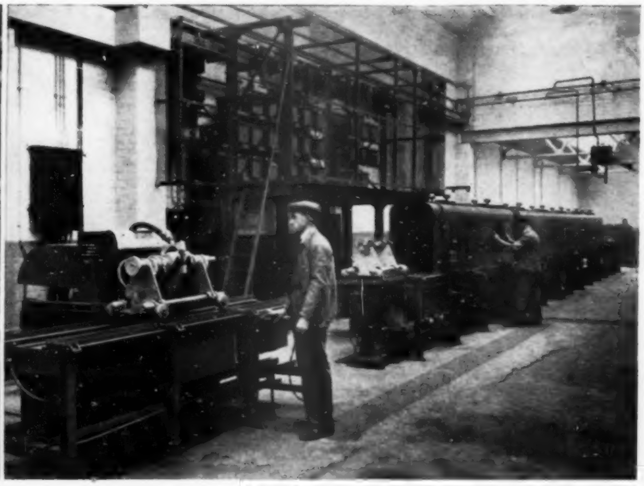
A typical example of progressive surface hardening is the treating of track pins used for coupling tractor links. Fig. 5 shows a standard unit for such work. The pins are fed downwards at a constant rate through the inductor which continuously heats the surface to the required depth. The pin enters a spray quench as it emerges from the bottom of the inductor and the finished pin is discharged from the bottom of the machine. Gudgeon pins, rocker arm shafts, rear axle shafts are other typical parts treated progressively.

The process is not limited to articles which are circular in section. Flat faces can equally well be surface



Courtesy of Messrs. Ambrose Shardlow & Co., Ltd.

Fig. 2.—Experimental station for crankshaft hardening.



Courtesy of Messrs. Ambrose Shardlow & Co., Ltd.

Fig. 3.—Seven-station tunnel line for crankshaft hardening.

hardened either by the one-shot or the progressive method. Special inductors, often with laminated cores, designed for efficient surface heating are used. A good example is the progressive hardening of the flat rubbing face of tractor links. Fig. 6 shows the cross-section of a tractor link showing the hardened zone.

The same general principles applied to external hardening are also used for hardening internal faces such as cylinder bores, oil well tubing, bushes, etc. The power input for internal hardening is of a higher order than for external work since the forces outside the inductor loop are weaker and the heat is dissipated into an increasing area.

Fig. 5.—Induction heating unit for the progressive surface hardening of steel pins.

Gear Hardening

Carburised gears have a uniformly thick case following the contours of the tooth and root form. It is not practicable to give this same uniformity with an induction hardened gear.

Inductors for gear treatment are circular with as good an electrical coupling as practical, there being no benefit in having an inverted tooth formation for the inductor. There is always a tendency to heat the tip of the tooth more than its root, firstly, because it is nearer the inductor, and secondly, because there is less mass per unit of surface area. With gears finer than 6 pitch, the teeth are through-hardened, no matter what power density or frequency is used. With courser gears and using a power density of 8–10 kw./sq. in. of pitch diameter, a softer core can be left at the base of each tooth. It is obvious that both for one-shot and progressive treatment, a comparatively large total power is needed, even for quite small gears.

Fig. 4.—Two of four vertical units for automatically hardening crankshafts.

Fig. 6.—Sections of tractor link showing surface hardened face.

There are a number of very interesting examples of large gears of 3 or 4 pitch which are hardened with a power density of 1 or 2 kw./sq. in. of pitch diameter. A plain carbon steel of low hardenability is used, and the combination of the peripheral heating and low hardenability gives the desired results and produces gears very suitable for tractors. Machine tool makers are usually satisfied with gears with through-hardened teeth coupled with good root hardening. The absence of distortion after treatment is of great advantage in the heat treatment of gears.

Very large gears, too large for treatment in one operation, are treated tooth by tooth or, rather, valley by valley. A special inductor which traverses across each valley, heats the adjacent faces of two teeth and the root, the tip of the tooth being left soft. For this operation valve equipment is necessary.

Sometimes carburised gears are finally hardened by induction heating, the advantage being that the carburised part can be finished, ground and shaved while soft and the subsequent induction heat treatment causes no distortion.

Some Metallurgical Considerations for Surface Hardening

The steel structure prior to surface hardening is of great importance, particularly in the case of very thin cases requiring very short heating times. Where possible, as-cast or spheroidal structures should be avoided. Usually a fine grained normalised condition is quite satisfactory, although for very thin cases a sorbitic structure may be needed.

Where adopted, the normalising treatment is carried out on the forging, or rolled stock, before machining so all machining operations are performed on the steel in this soft condition so that machining speeds are high and costs low.

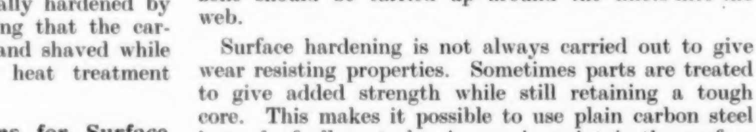
The surface heating only embraces a very small percentage of steel and there usually remains ample cold rigid stock to hold the part to its original dimensions. Distortion in surface hardening is small and often no rectification is needed. In other cases, finished grinding of the hardened parts corrects any faults.

There is ample proof that the induction hardened layer is under compressive stress, a favourable condition for resistance to fatigue.

With properly treated parts, there is a gradual transition from the hardened case to the unhardened core, and there should be no tendency for the case to flake off.

This transition zone is under tensional stress and so has less resistance to fatigue. In the case of progressive treatment, this transition layer is well down in the body of the steel, but attention must be given to it in the one-shot processes. The width of the hardened band should be adjusted so that the transition zone does not outcrop at a position of concentrated stress. An example is a crankshaft. The hardened band should stop short of the fillet. In special cases, as for example, where journals have to take side thrust the hardened zone should be carried up around the fillets into the web.

Surface hardening is not always carried out to give wear resisting properties. Sometimes parts are treated to give added strength while still retaining a tough core. This makes it possible to use plain carbon steel instead of alloy steel. A case in point is the surface hardening of motor-car rear axles. The shafts are machined in the soft normalised condition and then surface hardened along their entire length to give a fairly deep case. The shafts are thus given adequate



Courtesy of Messrs. A. P. Newall & Co., Ltd.

Fig. 7.—Machine for continuously hardening steel bars.

torsional strength—superior to that obtained with a heat treated alloy steel and with a great saving in cost.

Through-heating

Induction heating finds wide application for heating right through the section to a uniform temperature. In the case of surface hardening, the object is to heat the skin quickly before the core reaches hardening temperature. This is not so with through-heating and consequently much lower power concentrations are applied, so as to allow adequate time for the heat flow by conduction. The greater the diameter of the stock, the less must be the power concentration to permit longer time for the heat flow by conduction. A power input of about 1 kw./sq. in. of surface area for a 1 in. diameter stock is reasonable and for larger diameters, the power should be reduced in proportion to the reciprocal of the diameter.

An interesting case is the through-hardening and tempering of steel for stock. Fig. 7 shows such an installation and Fig. 8 the inductor. The steel bars are progressively fed through a long inductor of low power concentration to heat the bar to a uniform temperature. As they emerge from the inductor, they enter a spray quench for hardening. The hardening bar can then be passed through a second inductor with a lower power input to heat it to tempering temperature. Separate motor generators and control gear supply power to the two inductors. Where output is small, a unit with one inductor and one generator is used for both hardening and tempering, the bars after hardening being repassed a second time with a lower power input for tempering.

Heating is comparatively rapid and a suitable atmosphere can be maintained within the heated zone to prevent surface decarburisation. The bars are rotated slowly about their longitudinal axis as they are fed forwards, and provided the discharge guide and quench are properly maintained, commercially straight bars are produced. By changing inductors and adjusting roller gear, bars of different diameters can be treated. The mechanism can handle square, hexagon and other sections as well as round.

The power consumption for hardening and tempering varies from 500 to 550 kw./ton, depending on the steel being treated. An installation with a 100 kw. generator for hardening and 75 kw. for tempering will produce 800–1,000 lb. of finished bars per hour.

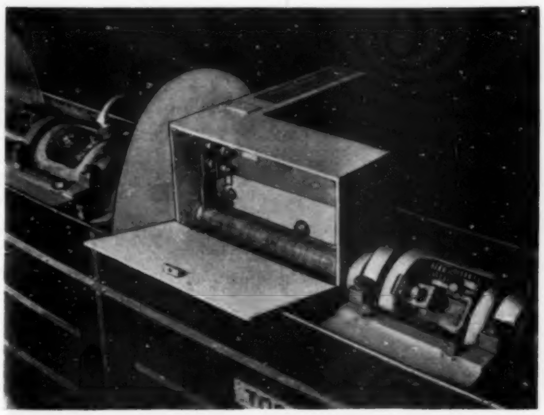


Fig. 8.—Inductor and driving gear box for bar stock hardening machine.

Courtesy of Messrs. Geo. Cooper & Son, Ltd.

Fig. 9.—Heater station for heating the ends of steel pins for bolt forging.

Heating for Forging

This is another example of through-heating calling for relatively low power concentrations, and, like all through-heating work, the lowest frequency compatible with the cross section is preferable due to the greater depth of energy penetration.

Induction heating is best suited to mass production of similar forgings. The earliest installations had single helical coils designed to heat the particular articles and, depending on the nature of the forging operation, either part or the whole of the piece was heated. There were many examples of these sample units installed in America for the various operations in connection with shell production.

Using only one inductor on a generator for heating one piece of steel does not permit the most efficient use of the generator. The circuit impedence changes very considerably during the heating cycle, especially between the magnetic and non-magnetic states. In addition, changes of power factor call for switching on extra condensers during its cycle.

Developments have smoothed out the load. In some cases multiple inductors, operating on a staggered cycle are advisable, and in others a long inductor capable of heating a number of parts at a time is used. Cold blanks are fed in at one end and are passed progressively through the inductor, coming out hot at the other end.

This continuous form of heating has so many advantages that it should be adopted wherever possible. In its simplest form the inductor is a long helical coil, its length being fixed by the time required to heat uniformly through the section and the output required. The slugs or billets to be heated are pushed through by mechanism operating on the cold slugs, progressively pushing out the hot ones at the other end. The inductor can be arranged at any angle from horizontal to vertical, depending on the work, but a vertical set-up is best as this causes least rubbing on the inside lining of the coil inductor. Nowadays, due to improvement in other forms, long helical inductors are being used for small slugs only.

Helical coils, especially the long ones, have two main disadvantages. In the first place, the inner lining is

subject to wear by the rubbing action of the work. Many improvements, such as water cooled skids, have been used with advantage, but the inherent difficulty still persists. Secondly, the inside of the coil is somewhat inaccessible for lining maintenance for the clearance of obstructions, etc. To overcome these problems, channel type or skate type inductors have been developed. These are virtually coils wound in a rectangular form, the long axis of the rectangle being fixed by the heating time and rate of travel of the work, and the short axis by the cross section of the workpiece. Sometimes the two ends are turned upwards above the main level of the inductor to allow the billets to be progressively passed through.

The channel type inductor is open top and bottom, giving complete accessibility for maintenance of refractory linings, etc. Work can be carried on mechanism quite separate from its inductor, and so all rubbing on its lining is avoided.

There are many examples such as the making of bolts, flanging of axles, forging of rings, or gear blanks on upsetting forging machines, where only the end of a steel pin or bar is heated for forging or upsetting. In such cases the parts are progressively fed through a suitable channel inductor and that part within the inductor is heated.

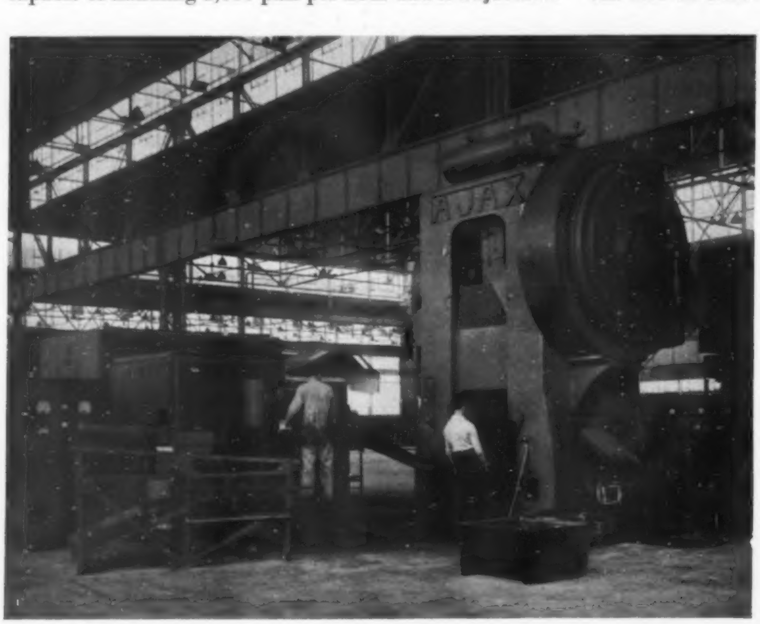
Fig. 9 shows the heating of the ends of steel pins for bolt making. The apparatus consists of a slowly rotating turntable with a series of radial arms capable of gripping the pins over a fixed arc of rotation. A channel type inductor, in this case curved to suit the turntable radius, is arranged over a short section. The pins are fed into charging holes around the periphery and, as their lower ends pass through the inductor, the upper ends are held by grips on the radial arms. At the finish of the heating cycle, the pins are released and drop down a chute alongside the forgeman. Each unit is capable of handling 2,000 pins per hour and is adjustable for different lengths of stock and heated length. It is a typical example of end heating work and adaptations for other applications can be visualised.

Channel inductors are also very useful when the whole of a slug or billet must be heated, the billets being carried through the inductor on a moving refractory hearth. Fig. 10 shows one of 12 heater stations built on this principle. In this case the hearth is circular. The cold billets are charged on the refractory ring hearth which is rotating at a constant speed. The inductor is fixed over a portion of the hearth and the billets are heated as they pass through. At the discharge end they are wiped off, by automatic striker gear, and drop down a chute conveniently to the hand of the operator. The whole operation is very simple and provides a constant supply of hot billets at regular intervals which is ideal for mass production.

The turntable billet heater has practical limitations as regards billet length. For long billets a straight channel type inductor can be used. The moving hearth in this case would be of endless chain formation with suitable refractories built up on the links to carry the billets. Obviously such a mechanism is not quite as simple as the turntable.

The induction heating equipment is expensive but it has many advantages, some of which are :—(*a*) Considerable reduction of scale, giving a marked saving of steel. (*b*) Improved die life due to the reduction of scale ; (*c*) Only a few minutes is required to restart from cold ; (*d*) The ability to heat one—that portion that may be necessary ; and (*e*) Ideal working conditions due to absence of smoke and most of the heat.

The power consumption depends on the size of the piece and the temperature to which it is heated, but usually it is within the range of 350–500 kw./ton of heated steel. It is, of course, not limited to steel but can also be used for heating any non-ferrous metal.



Courtesy of Messrs. John Garrington & Sons, Ltd.

Fig. 10.—Turntable unit for delivering continuous supply of hot billets to the forging press.

Brazing and Soldering

This is an application of induction heating of vastly growing importance and has received a great impetus by the introduction of the lower temperature brazing alloys. To produce a good braze, the faces to be joined and, the brazing alloy, must all be raised to the right temperature at the same time. Proper inductor design makes it possible to concentrate power in specific areas as may be necessary when light and heavy parts are joined together.

Common examples are the brazing of carbide tool tips, bicycle frames, flanges or brackets on shafts, etc., the soft soldering radiator assemblies and similar parts.

Where necessary, bright copper brazing under reducing atmosphere conditions can be carried out but usually brazing is done in open inductors using a suitable flux. Very little oxidation takes place because the heating time is short and, in any case, is only local. Sometimes local hardening and copper brazing

Courtesy of Messrs. Wm. Jessop & Co., Ltd.

Fig. 11.—Induction brazing of tungsten carbide tool tips.

are carried out at the same time—for example, on distributor cams.

There is to-day a considerable increase in the brazing together of simple components to make intricate assemblies which had previously been produced from machined casting or forgings. The saving is obvious and much is now known about the various brazing alloys, fit tolerances, etc., so that ample strength can be assured. The various components are assembled with prepared brazing wire inserts and flux. If necessary, the parts can be held in jigs while being induction brazed.

By comparison with surface hardening, heating for brazing must be much slower. Heat must penetrate deeply into the joint and so the lower frequencies are advisable. Heating times vary with the size of the part but are usually between 5 and 20 seconds.

Conclusion

It is hoped that this brief review will give a picture of the proved applications but new uses are being found daily. Induction hardening has made it possible to use plain carbon steels where previously more expensive alloy steels were required. Surface hardening as compared with carburising is much quicker and cheaper and distortion is avoided. As regards heating for forging, pressing or rolling, this is the youngest application and so far only the fringe of the field has been tackled. One cannot fail to be impressed with the clean working conditions of an induction heating forge shop and so human endeavour, as well as giving a better product, is clearing away yet another "sweat" job.

Engineer Buyers and Representatives Association

Sir Herbert G. Williams, M.Sc., M.Eng., A.M.I.C.E., presided at the recent well attended first general meeting of the above Association, held at the Waldorf Hotel, Aldwych, W.C.2, at which he read over the operative paragraphs in the minutes of the inaugural meeting, when the present general secretary and honorary treasurer were elected and a provisional Council formed with powers and authority to define qualifications for membership, make additions or modifications and generally do what might be necessary to put the Association on a sound and proper basis.

With scarcely any discussion and no dissentient the meeting approved all the work of the Council and adopted the Council's report of the memorandum and Articles of Association as registered. The President, honorary Vice-Presidents, the Officers and members of the Council named in the Articles of Association were confirmed in office, but the Council was enlarged to nineteen. The full list of Officers and Council is as follows :—

President : Sir Herbert G. Williams, M.Sc., M.Eng, A.M.I.C.E.

Honorary Vice-Presidents : Mr. C. Edgar Allen, A.M.I.Mech.E., A.M.I.E.E., Mr. L. E. Van Moppes, and Mr. T. Ratcliffe.

Honorary Treasurer : Mr. L. C. Thornton.

Council : Messrs. Harold Beaman ; Reginald S. Beard ; J. Brogden ; A. Butterworth, M.I.P.E.; James H. Cole ; John J. Haig ; Stanley H. Honer ; H. S. Hull, M.I.Mech.E., M.I.P.E.; Col. D. R. Johnson ; Thos. E. Parker ; Bernard Pidd ; F. Le D. Rettig ; J. A. Simmonds ; Herbert Smith ; J. R. Start ; and R. A. Straker-Nesbit, A.I.P.E.

General Secretary : Captain Arthur J. Dronsfield.

The address of the Registered Office of the Association will remain at 47, Victoria Street, S.W.1.

Casehardening Steels in Cyanide-Containing Salt Baths

(Continued from page 36)

Fig. 24 shows the case produced on a mild steel bar carburised for 4-hours at 950° C. in an accelerated bath called "Rapideep" and air cooled (0·055 in. case).

In Fig. 25 is shown the case produced on mild steel by carburising in a "Rapideep" bath for 2-hours at 950° C. The case was finally hardened with a water quench from 780° C.

Depth hardness curves obtained on a $4\frac{1}{2}$% nickel-chrome casehardening steel are shown in Fig. 26, whilst the same test pieces, after sub-zero cooling to –76° C. in a "Drikold" bath are shown in Fig. 27.

The marked improvement in hardnesses by the simple sub-zero cooling treatment to break down residual austenite will again be observed. The surface hardness of the case has increased by as much as 200 V.P.N., approximately, whilst the hardness at the point of maximum hardness has risen by 100 V.P.N., approximately.

One of the great advantages of the salt bath method of carburising is the high output obtainable from a relatively small plant. Parts when being carburised in salt can be carburised in bulk and in close proximity to one another and certainly do not require the careful spacing so necessary if satisfactory results are to be obtained by pack or gas carburising methods.

Fig. 28 shows an installation of salt baths employing cyanide/carbonate, or accelerated cyanide baths for casehardening purposes.

Rough Copper Price Down

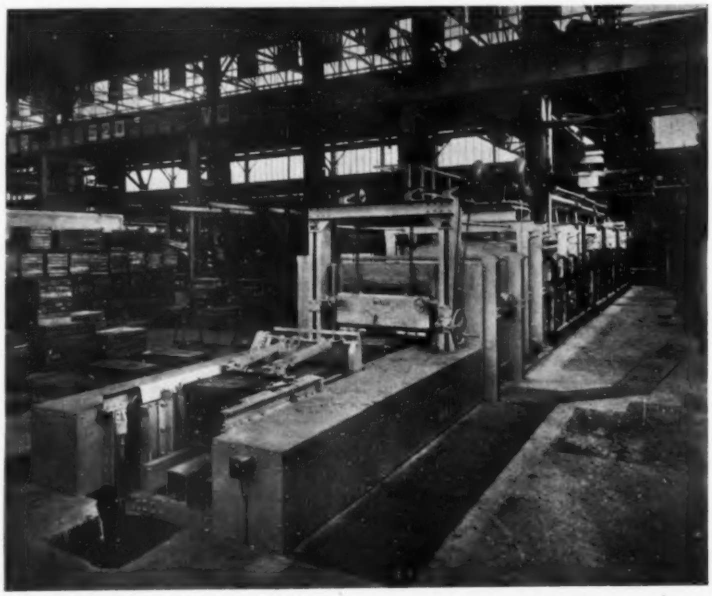
The Ministry of Supply announces that as from 27th April, 1949 their buying price for rough copper 97.25% minimum, has been reduced by £15 per ton to £90 per ton ex makers' works, for delivery by the end of the third month forward. For rough copper running 99% and over, there is an extra of £1/10 per ton.

Some Recent Heat Treatment Furnace Installations

Progress in Design and Application

Heat treatment is essential in practically all operations involved in forming of metal products, and in giving the material the final structure likely to have the desired physical properties. Developments in both ferrous and non-ferrous materials have necessitated more critical time and temperature limits, while improvements in furnace equipment have been accelerated by mechanical handling of the products treated and by atmosphere control. Reference is made to interesting features associated with some recent installations.

THE primary object of most heat treatment operations is the attainment of a final structure in the ferrous or non-ferrous material which will give the desired physical properties suited to the service conditions for which it is to be used. Additional refinements are frequently desirable, such as bright or clean finish on the material treated, in which scaling, decarburisation and other chemical reactions are eliminated from the heating process. But more attention is now being given to the heating of ferrous and non-ferrous materials for their preliminary forming operations because of its influence on the final structure, as well as on manipulation, and greater care is being exercised in controlling temperature and in protecting the material. Satisfactory results in the achievement of these objectives depends largely upon the design of the furnaces for the work involved, its equipment, the material or component to be treated, and on those responsible for carrying out the operations.



Courtesy of Gibbons Bros., Ltd.

Fig. 1.—The charge end of a walking beam mill furnace, for heating non-ferrous slabs. Note the slab magazine.

The first function of a heat treatment furnace, whether it is heated by gas, oil fuel, or electricity, is to give a satisfactorily product at low cost, consistent with uniformity of heating. The cost of the heating medium employed, temperature and atmosphere control, and other phases in heating operations are really incidental to the main consideration which involves the quality of the finished product and its overall cost. Thus, when making a choice it is important to keep in mind the need for producing a high grade product at low cost, using that form of heating medium and that type of equipment which will give these results under the conditions that operate in the works at which new heat treatment plant is contemplated. Many factors are involved in the final choice ; local conditions often have an influence, but the guiding principles are concerned mainly with flexibility and ease of control. With the trend towards mass production in many industries, the duty demanded of heat treatment furnaces may amount to a precise and clearly defined treatment and output. To meet this requirement furnaces are so designed that they operate with such precision as to be located in the production line, in which case the allowable margin to cover contingencies and unknown factors is much reduced, but a fair measure of flexibility of output and range of temperature is needed in many types of heat treatment plant for general purpose use. With regard to ease of control there must usually be a compromise between an installation so far mechanically controlled that it may be regarded as "fool proof" in operation and a complicated mechanism which involves special handling.

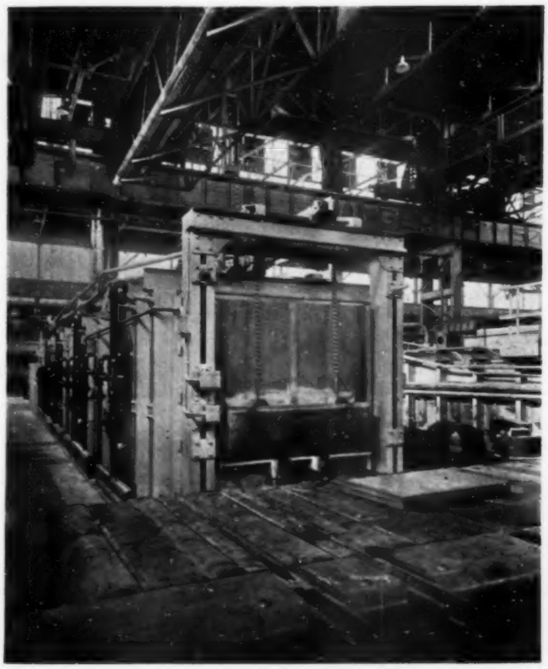
Most heat treatment methods are carried out in batch, continuous, or semi-continuous furnaces. The batch method, with the simple box-type chamber, was developed first and will always be popular because of its adaptability to products varying widely in size, quantity, and even type of treatment. When the output of a product requiring the same heat treatment is fairly constant, an opportunity is provided for using some type of furnace in which the material to be processed is automatically handled, involving a continuous furnace.

Apart from the normal methods of heating, high frequency heating is now being successfully applied to heat treatment operations and, when special arrangements are made for dealing with particular products, a high output of treated products is made possible. Some recent furnace installations, which are briefly described in the following notes, can be regarded as typical of the developments in heat treatment equipment and show the trend of improvements in the various operations involved.

Heating Furnaces

Modern furnaces for heating slabs and ingots are becoming increasingly mechanised and less subject to manual control; in addition, stringent metallurgical specifications now insisted upon have brought revolutionary changes in furnace technique and design. An interesting example is a recent installation at the Birmingham Kynock Works of I.C.I. LTD. (Metals Division) which shows the progress made in industrial furnace engineering for the following description of which we are indebted to Mr. M. van Marle, director of GIBBON BROS. LTD.

The furnace, which is illustrated in Figs. 1 and 2, feeds heavy non-ferrous slabs to a mill for the purpose of rolling into sheets of various thicknesses and lengths. It can be operated by push buttons or controlled by a master clock which sets the rate of delivery of the heated slabs. These are delivered on to the mill conveyer table and simultaneously a cold slab is fed into the entrance end of the furnace. While this is taking place a slab is mechanically removed from the magazine and placed on the charge table ready to be passed into the furnace.

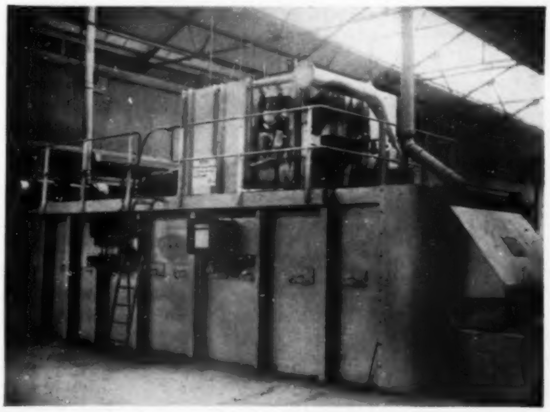


Courtesy of Gibbons Bros., Ltd.

Fig. 2.—The discharge end of the same furnace with a slab on the mill roller table.

The furnace is divided into four zones, each governed by a Reavell-Askania control equipment working in conjunction with pyrometric temperature recorders of Messrs. KENT'S manufacture. These instruments also control the air/gas ratio, and therefore the composition of furnace atmosphere. The chimney stack is also under the same control, and the heating chamber is therefore maintained at a constant positive pressure.

The furnace is 5 ft. wide internally and has a total heating length of 75 ft. The slabs are conveyed through it by a refractory walking beam conveyer. The conveyer extends to the end of the charging table and is supported on a steel carriage moving upon a series of rollers housed at the end of counter-balanced levers. It is driven by two motors, one for operating the horizontal and the other the vertical movements. These motors are electrically interlocked so that no vertical motion can occur while the horizontal movement is taking place, and



Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 3.—An oil fired convection heated aluminium billet furnace.

vice versa. The horizontal stroke can be varied to ensure that slabs of different lengths arrive at their proper positions at the exit end of the furnace.

The slab magazine is located at the end of the charging table, from which a slab is removed to the table by the action of the walking beam. The magazine is driven by a motor, which is electrically interlocked with the conveyer motors and which raises the pile and brings the top slab into position for removal to the charging table as and when it is required by the furnace.

The charge door is fitted with hinged metal flaps at its lower edge, which enable the ingoing slabs to pass into the furnace without operating the door. The discharge door is motor operated, the door being opened and shut by the action of a slab extractor gear. This gear has two parallel arms which enter and remove the slabs from the furnace and deposit them on the mill table. Electrical interlocks permit the extractor arms to enter the furnace only when the door is open. The door shuts immediately a hot slab has been extracted. A water seal is fitted along both sides and ends of the furnace beneath the beam conveyer, to prevent the infiltration of air into the furnace chamber.

The furnace is fired by towns' gas on the Gibbons-Webb roof combustion principle, designed to ensure uniform distribution of temperature over the surface of the slabs. This system embodies a roof perforated with regularly-spaced holes of uniform size, through which

pre-heated combustion air flows in the form of small jets into the fuel gas below. The gas is introduced through ports regularly spaced along the spring line of the roof arch, and the resultant combustion gases spread uniformly over the load. The furnace gases flow along the chamber towards the charge end, preheating the cold incoming slabs on their way. Eventually, the gases leave the chamber through governed ports at the charge end and pass into the recuperator chamber incorporated in the roof of the furnace. After flowing over the recuperator pipes, they finally pass to the chimney at a relatively low temperature. Each combustion section has its own metallic recuperator, with a control valve operating on the cold air inlet side.

The furnace has a capacity of 10–12 tons of non-ferrous slabs per hour, at which output the fuel consumption is approximately 0·5 cu. ft. of town's gas per lb. of copper heated to rolling temperature.

Forced convection or recirculation furnaces have usually been associated with gas or electric heating. The adoption of this method on a large scale has been developed from the small tempering furnaces of the tool room, but the use of convection heating with oil fuel is almost wholly a post-war development. The installation of an oil fired convection heated billet furnace at the Dolgarrog Works of The Aluminium Corporation Ltd., therefore, is of considerable interest.

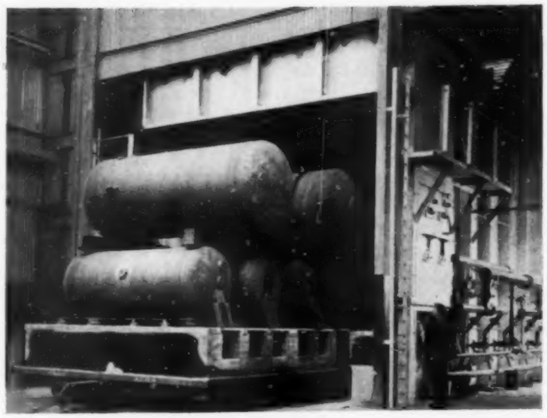
The greater proportion of the heat transfer in ordinary furnaces is by radiation, but aluminium does not readily absorb heat in this form. To speed up the heating, it is necessary to increase the rate of heat transfer by adding another kind of heating to that of radiation. This is accomplished by means of forced convection and this furnace, illustrated in Fig. 3, is therefore smaller in size than the older furnace of the same output which it replaced.

The oil fuel is burnt in a firebrick lined combustion chamber connected to the inlet of a powerful circulating fan which also draws gases back from the furnace chamber. The mixture of the recirculated gases and fresh products of combustion pass out of the fan into a duct in the top of the heating chamber. From the duct the gases are distributed throughout the length of the furnace, flowing at high velocity over the surface of the aluminium billets. The gases are gathered in the base into ducts which connect with longitudinal ducts on top of the furnace leading back to the circulating fan.

The aluminium billets are conveyed through the furnace on four strands of roller type malleable iron chains having nickel-chrome steel pins. The chains are driven by an electric motor through a variable speed gear drive. In order to accommodate variations in the stretch of the four chains, individual tensioning devices are incorporated.

The temperature of the furnace is controlled by a two-point recording controller connected to two thermocouples, one in the furnace, and the other in the inlet eye of the circulating fan. Both control points operate one motorised fuel valve so that if the temperature at either point exceeds that set in the instrument, the valve moves to its minimum opening position.

The furnace, which has been designed and built by The Dowson and Mason Gas Plant Co. Ltd., is protected from failure of the air or oil supply, by pressure operated switches which actuate a solenoid valve in the oil supply pipe. Its output is 2,800 lbs. of aluminium billets per hour, heated to 500° C., with an oil consumption of approximately 7½ gallons per hour.



Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 4.—A large oil fired furnace for stress relieving Rutter accumulator shells as well as all types of receivers and vessels for oil refineries.

Stress Relieving

Heat treatment is frequently necessary to remove stresses from components; in some cases, as with pressure vessels stringent rules and safety codes govern many of the production processes, and stress relieving is one of the most important of these processes, which necessitates accurate control of temperature throughout the operation.

Companies specialising in the manufacture of pressure vessels have, until recently, depended on towns' gas or clean producer gas for heating their furnace because these fuels allowed precise control of the comparatively low temperature of 650° C. The advances in industrial furnace technique and the application of oil firing equipment has enabled a large stress relieving furnace to be built by The Dowson and Mason Gas Plant Co., which uses heavy fuel oil with very satisfactory and economical results. This furnace, shown in Fig. 4, has been installed at the works of Cochran and Co., Annan, Ltd., and is used for the stress relieving of boilers, Ruth accumulators and all types of pressure vessels. Inside, the furnace is 16 ft. 6 in. wide by 16 ft. 6 in. high by 27 ft. 6 in. long and its design embodies certain features of interest.

The vessels to be heat treated are loaded on a bogie and moved into the furnace by means of the shop crane whose hook is connected by wire rope running round tail pulleys to the bogie. Roller bearings are used for the wheel axles, sand seals on the sides and ends of the car preventing the escape of hot gases to the under-carriage.

A very desirable feature in a stress relieving furnace is that the walls shall have a low heat storage capacity which will enable fast heating and controlled cooling. The characteristic of pressure vessels and similar articles is their relatively large bulk in proportion to their weight; consequently, if furnace walls are built of heavy refractories such as firebrick, they absorb an excessive quantity of heat in relation to that received by the article under treatment. The use of lightweight refractory and diatomaceous block insulation in this furnace, the total thickness being not more than 9 in., makes for high overall efficiency.

The furnace is divided into two self-contained and independent zones, having burners arranged along the bottom of each side wall. The burners fire into refractory

channels between piers built on top of the bogie, the hot gases after circulating round the articles being treated, pass away through ports in the walls at front and rear.

The high flame temperature of the fuel oil necessitates special attention to the uniform and adequate dispersal of the heat generated by each burner. This is achieved by the use of Carbofrax tiles covering the refractory combustion chamber channels in the top of the bogie. The high thermal conductivity of Carbofrax keeps the combustion chamber temperatures relatively low. This is further enhanced by the arrangement of the tiles which cause a circulation of gases by the action of the flame moving at high velocity along the underside.

The oil burners are of the Laidlaw Drew low pressure type supplied with air at 22 in. W.G. and oil at 20 lb.

—Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 5.—Typical gas carburising installation using prepared towns' gas, as a carburising medium.

per sq. in. The oil circulating main is unique, consisting of concentric tubes on each side of the furnace, the oil flowing through the inner tube to the front, and returning between it, and the outer tube to the rear. A combined heating and pumping unit circulates the heavy oil from the storage tank through the supply mains to the burners.

Typical operations are the heating of 30 to 40 tons of steel in periods of 4 to 7 hours, followed by 2 hours' soaking at 650° C. and slow cooling in the furnace. The oil burners are automatically controlled during the soaking period to maintain a constant temperature in the furnace.

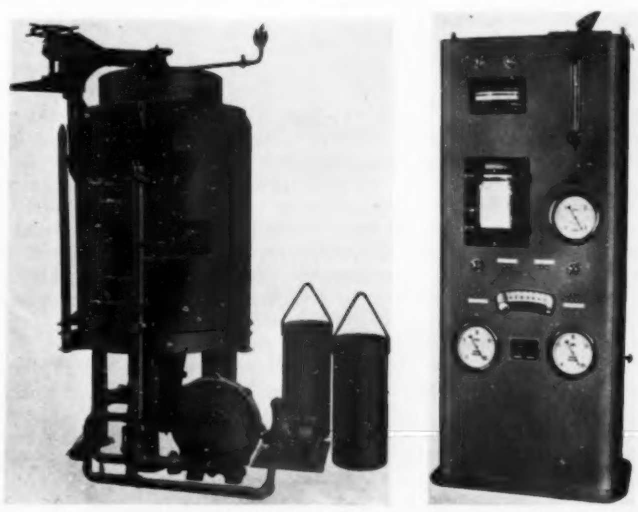
Carburising Furnaces

Developments have been introduced in the equipment of the well-known Homocarb method of carburising of The Integra Co., Ltd. The standard equipment now includes a natural cooler which enables the heat-treater, at the end of the soak, to cool the load rapidly right in the furnace, from the carburising temperature of about 900° C. to a transfer temperature of about 760° C. With the load protected by the Homocarb atmosphere it can be safely transferred, on a falling heat, either to a cooling unit or to a quench tank, giving improved carburising results. A further development is the use of the equipment for gas cyaniding by means of an ammonia flowscope. In this method the heat-treater regulates the composition of the cyaniding gas by adjusting two controls on the furnace panel. To provide carburising gas, Homocarb fluid is pumped into the furnace at a controlled rate according to the setting of the flow setter. When the fluid enters the furnace chamber, it becomes a rich carbon gas, and to this is added ammonia gas from an ammonia tank. The rate of addition of ammonia is also regulated by an ammonia flow setter on the instrument panel.

Very full information was given in an earlier issue of this Journal concerning the first installations employing the Wild-Barfield patented prepared towns' gas carburising. These installations employ high quality heat-resisting removable retorts, which are transferred to controlled cooling pits after the actual gas carburising. A large number of installations are on order and these, whilst adhering to the well proven principle of employing prepared towns' gas and diffusion, incorporate a number of new features. One installation is in course of manufacture for the gas carburising of parts of dimensions 7 ft. 6 in. diameter by 2 ft. 3 in. deep and weighing $2\frac{1}{2}$ tons. Such parts are being accommodated in a horizontal type furnace using a heat-resistant retort of dimensions 9 ft. × 9 ft. × 4 ft. Prepared towns' gas from a large gas preparation unit is fed to this retort by way of a series of multiple inlets, which allows of even distribution of the gas to all parts of the work without using a fan. Another installation for the gas carburising of parts 5 ft. 6 in. long by 1 ft. 6 in. diameter and weighing $1\frac{1}{4}$ tons, is in course of manufacture. This is being done by using a large vertical furnace with a removable retort. A number of other installations are almost completed, these being required for automotive components. These employ a lighter weight fixed retort the work after carburising being transferred to controlled cooling pits.

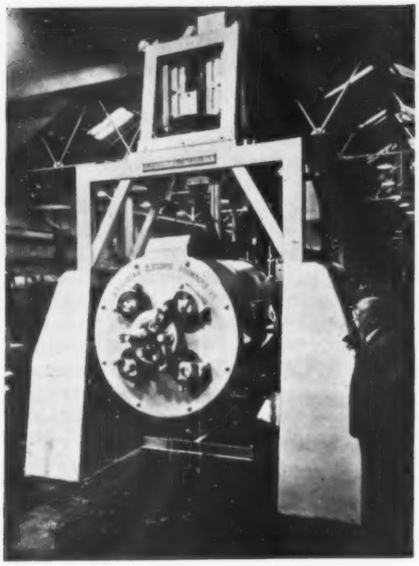
Fig. 5 shows a typical installation for the gas carburising of large gears, shafts, pinions and other parts.

It is well known that in many carburising systems a carrier gas produced in a gas generator is employed as

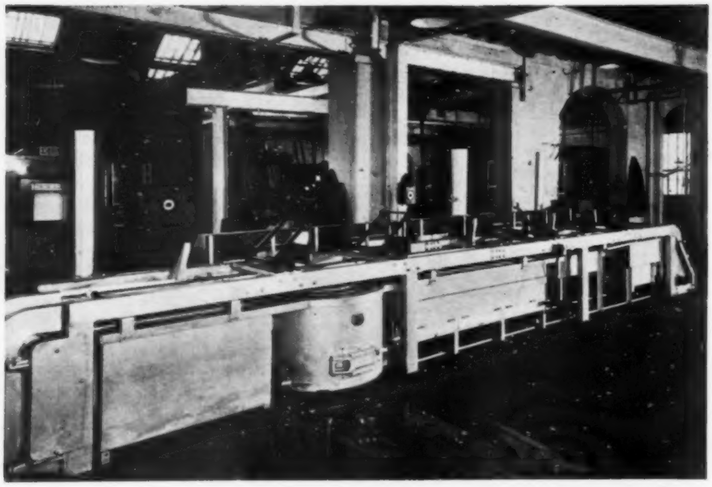


Courtesy of Incandescent Heat Co., Ltd. Showing the unit enlarged in relation to the furnace.

Fig. 6.—Towns' gas fired radiant tube cell furnace with master control unit for carburising with "Lithanol" vapour.



Courtesy of Birlec, Ltd.
Fig. 7.—A rotary gas carburising installation.



Courtesy of Imperial Chemical Industries Ltd.
Fig. 8.—C.A. type plant for austempering of spring steel parts.

a diluent for hydro-carbon gases which would by themselves cause soot and coke to form on the steel surface and retard carburising. For this reason the capital outlay on a small batch type gas carburising furnace is often raised by the cost of a gas generator. There are many mineral and vegetable oils which may be used alone without the necessity of installing a gas generator to dilute the carburising vapours created in the working chamber of a gas carburising furnace. Lithanol is one of these carburising agents plus lithium compounds which are introduced into the work chamber in solution with the fluid, as in the towns' gas fired radiant tube cell furnace by The Incandescent Heat Co. Ltd., shown in Fig. 6.

In all gas carburising furnaces there is the possibility of oxygen and water vapour being introduced as an absorbed film on the surface of the metal to be treated or through the seals, furnace doors and walls by osomosis, but the presence of very small quantities of lithium in the furnace atmosphere nullify completely the action of oxygen, carbon dioxide, and water vapour and consequently faster carburising is claimed to be obtained with Lithanol than with any other known carburising agent, as the action or decarburising elements is inhibited by the presence of lithium.

While in many cases it is convenient to use Lithanol without a carrier gas, the use of an endothermic gas generator is worthy of consideration in large insta lations and continuous furnaces as by this means the usage of carburising fluid is reduced by about half.

The modern process of gas carburising is a vastly improved procedure. The parts to be treated are loaded into a gas-tight chamber and heated to temperature in a neutral atmosphere ; when the whole charge is uniformly heated, a carburising gas is admitted and fed continuously until the required case depth is attained. The process is clean, quick and economical, and permits precise control. Much development in equipment for this process has been affected by Birlec Ltd., who have applied the principle to a wide range of furnaces. An interesting type from this range is the rotary drum batch furnace shown in Fig. 7. In this case the drum is mounted horizontally on trunnions and rotated at suitable speed. No charge carrier is needed, the work being loaded in bulk into the drum. Uniformity of case depth is assured by the movement of the work and the absence of a work carrier shortens heating up time and results in good thermal efficiency.

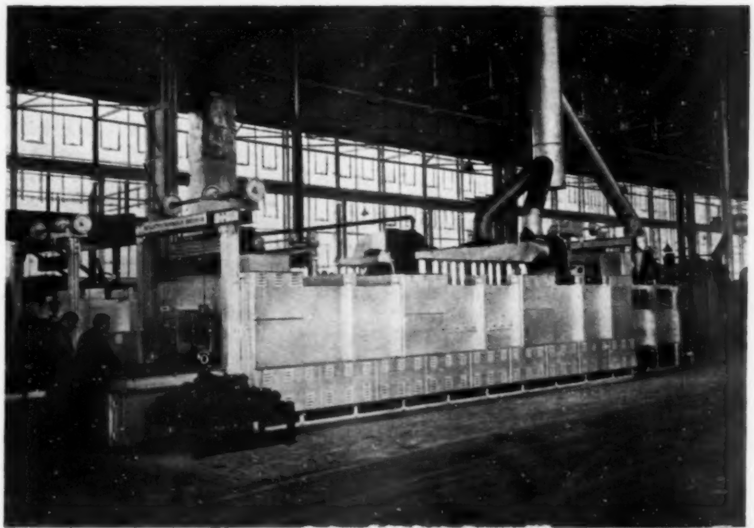
Salt Baths

Considerable attention has been given to the designing of mechanical means of handling work through the successive stages in salt bath case-hardening and heat treatment, particularly by Imperial Chemical Industries Ltd. Several totally enclosed types of plant have been built for case-hardening small parts. The parts to be treated being charged into a hopper and automatically transferred through the stages of preheating, immersion in the cyanide bath, quenching and emptying into a receiver at the finish of the process. Parts are poured into containers in the successive stages, the procedure being set in motion by operation of a push-button. Times of immersion in the cyanide bath are automatically controlled and can be varied as desired.

In another design of plant, known as a C.A. type, the work is suspended on jigs or wires and placed on a conveyer which runs across all the stages of the heat treatment operation, including preheating, cyanide bath treatment, quenching, washing and drying. Transfer from one stage to the next is by automatically operated swinging arms.

Austempering.—Considerable headway has been made in the austempering of small parts such as springs and typewriter components. Most installations consist of batch type furnaces, heating for austenitising being in salt or muffle furnaces, followed by quenching and transforming in molten salt baths. Some mechanised furnaces have been produced for austempering, such a plant being illustrated in Fig. 8.

Martempering.—This method of quenching steel to give high hardness, with minimum distortion and reduced danger of cracking, has made considerable



Courtesy of Metalectric Furnaces Ltd.

Fig. 9.—A normalising and cycle annealing furnace showing the cooling unit at the discharge end.

progress. Parts are usually heated in one salt bath, quenching being carried out in another, the latter being maintained a little above the temperature (known as the Ms point) at which martensite forms on quenching. The parts are held here until reaching bath temperature, and then air cooled. Special salt bath furnaces have been manufactured, fitted with agitators to keep the quenching salt moving quickly past the part being quenched, and with a device for filtering out high temperature salt carried from the heating bath into the quenching bath.

Annealing and Normalising

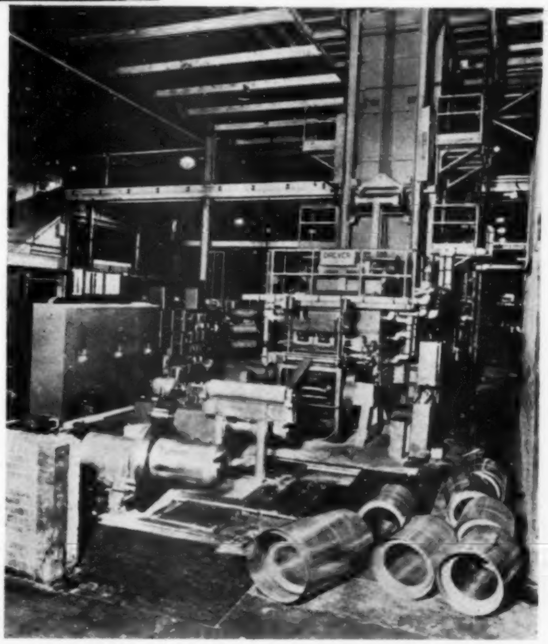
A composite continuous plant for the general heat treatment of medium carbon steel forging has recently been installed at the Bromsgrove Works of John Garrington & Sons, Ltd. by Metalectric Furnaces, Ltd. The post-war demand of the automobile and associated industries is such, that the trend towards continuous heat treatment, in this particular field, has been extremely rapid, and this plant, claimed to be the largest of its type in Europe, has been laid down to handle 3 tons of forgings per hour, ranging individually from a few ounces to 56 lb. The complete equipment, electrically heated throughout, has a total connected rating of 1,330 kw. and comprises :—

1. A continuous furnace for normalising and cycle annealing.
2. A continuous hardening furnace, incorporating automatic oil quench tank, with elevating conveyer, circulating pumps and cooler.
3. A continuous furnace for tempering.

Forgings of all types and sizes are treated in the plant, in which the conveyer belts, forming a flat, unbroken moving furnace hearth of great strength, are an extremely important part of the system. The type of link belt employed, embodying high quality nickel-chromium alloy castings, are suitable for carrying forgings of all shapes and sizes.

Fig. 9 illustrates the normalising and cycle annealing furnace and the cooling unit can be seen at the discharge end, which, fitted with a special fan system, is brought into operation only when the furnace is used for normalising.

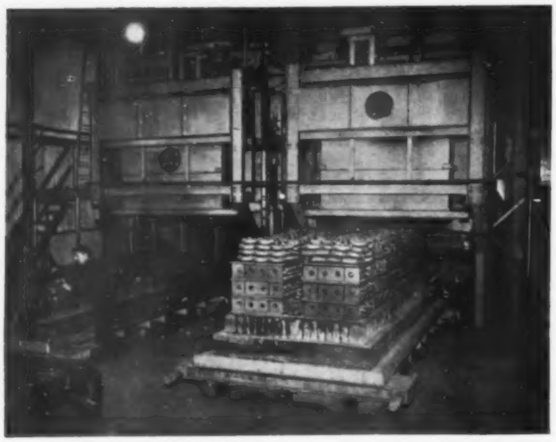
From the hardening furnace the forgings are directly quenched in an oil tank, and discharged automatically from the tank by a continuous conveyer of the wire belt type. An oil cooler is incorporated, together with circulating pumps, to ensure the maximum quenching effect. The tempering furnace is arranged in direct line with the hardening furnace and quench tank, and has a system of air circulating fans in the heating chamber, providing close temperature uniformity throughout, with a special cooling system at the discharge end to facilitate immediate handling of the treated components. Potentiometric type temperature regulating and recording instruments are included for each furnace, and the complete control equipment is installed in one central panel.



Courtesy of Incandescent Heat Co., Ltd.

Fig. 10.—The "Drever" has gas tight continuous strip annealing plant.

A new plant, shown in Fig. 10, now being manufactured by the Incandescent Heat Co., Ltd., and which will attract great interest, is the Drever gas-tight continuous strip annealing process for the economical high speed bright annealing of high, medium and low carbon steels, nickel and nickel alloys, beryllium copper and other copper alloys, etc., and the clean annealing of silicon steel and brass. Some points of particular interest in this new system are :—Improved quality through control of grain size ; uniform physical properties, and a



Courtesy of Birlec, Ltd.

Fig. 11.—A double installation of malleablising furnaces for whiteheart malleable castings.

clean bright surface; uniform heating throughout the entire length and width of the strip; speed of processing, enabling the material to be despatched the same day as it is rolled; low labour costs; clean operation; and low maintenance and replacement costs.

These plants are suitable for either electrical heating or radiant tube firing and can be supplied for outputs ranging from 100 lb. to 15 tons per hour.

Malleablising

The establishment of gaseous annealing in the whiteheart malleable industry is now an accomplished fact, and the practical success of the process as a whole has been amply proved, particularly the design developed by Birlec, Ltd., whose first full scale gaseous annealing furnace was installed at the works of Walsall Conduits, Ltd. about two years ago. A second furnace, of similar type, has since been in operation at Messrs. John Maddock & Co., Ltd., for annealing pipe fittings and miscellaneous engineering castings. So successful has this furnace been that a further installation was started up at the end of last year, making the first double installation for the gaseous annealing of whiteheart malleable castings. These two malleablisers are in production and a third is on order for the same firm; further, repeat orders have been received by Birlec, Ltd. for other firms and some nine malleablisers are in course of production for overseas buyers, indicate that the method is proving to be an important contribution to modern practice in the production of whiteheart malleable castings.

The double installation operating at the works of John Maddock & Co., Ltd. has a combined output of 24–30 tons of pipe fittings and miscellaneous engineering castings per week and is illustrated in Fig. 11. Both are electric furnaces of elevator type; the furnace proper, consisting of a rectangular gas-tight steel casing, closed on the four sides and roof, and lined with insulating and semi-refractory brickwork, on which the heating elements are mounted, is supported above floor level on a structural steel framework. The hearth, on which the charge rests, is in the form of a removable bogie (of which two are provided with each furnace), gas-tight sealing between it and the furnace proper being effected by means of a skirt on the furnace engaging with a sand seal on the bogie. Loading is carried out at floor level; the bogie is then transferred to a position under the furnace and elevated into the latter by means of a hydraulically operated hoist.

The charge is carried on the hearth, on an open shelf structure, made up of plates and supporting members. These are so arranged as to form, in conjunction with a number of centrifugal fans disposed in the roof of the furnace, a closed system through which the decarburising atmosphere is circulated continuously and uniformly to every part of the charge. The atmosphere, derived from the reaction of air (or other oxidising gas) with the carbon content of the castings, is automatically maintained throughout the annealing cycle within predetermined compositional limits, so as to effect decarburisation at the maximum rate without oxidation of the castings. The method employed for maintaining this control, which is one of the essential features of this process, involves the use of a CO_2 recorder through which samples of the atmosphere are fed continuously. The pointer of this instrument is equipped with a contact which opens and closes at 7%. If the CO_2 exceeds 7%, the contact closes, and thereby operates to close a valve on the regenerating air supply, so decreasing the volume of air fed to the furnace; if the CO_2 falls below 7%, on the other hand, the contact opens, and thereby opens the valve to increase the air supply. By this means, the CO_2 is maintained within the desired limits.

It will be appreciated that this atmosphere control system is a most important part of the equipment, since its failure may in certain circumstances lead to heavy scaling of the charge and possibly to the scrapping of several tons of finished castings. For this reason, it is desirable to have the control system duplicated, so that in the event of one instrument developing a defect, the second may take over. Provision of a second "safety" instrument on these lines is being made on the furnaces installed, and on all future installations, so as to eliminate the risk entirely.

The loading space dimensions of the furnace are 14 ft. long by 5 ft. wide by 2 ft. high. The full power rating is 300 kw., sufficient to heat an average charge to annealing temperature in 5–7 hours, but provision is made to reduce

Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 12.—Installation of vertical hardening and tempering furnaces for the heat treatment of automobile components.

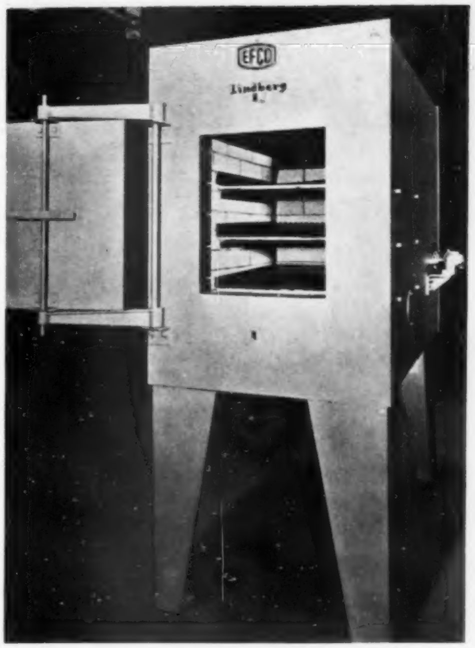
this rating during the soaking period to 90 kw., by means of a star-delta switching device, so reducing the maximum demand during the greater part of the annealing cycle. Temperature control is fully automatic, and excess-temperature safety devices are fitted to guard against any failure.

A forced cooling system which is built into the furnace structure is brought into operation at the conclusion of the soaking period. By this means, the temperature of charge and furnace may be rapidly reduced to a level at which unloading can take place without significant oxidation of the castings. The maximum obtainable rate of cooling is about 150°/hour, but slower rates are employed when the properties required of the castings make this desirable.

Batch Type Furnaces

In spite of mechanisation and the advantages which continuous automatic heat-treatment plant offers in the drive to reduce production costs, there are, and always will be, many applications where the product or the production does not lend itself to continuous plant and for which batch type equipments are far more suitable. These may range from the small units for hardening or tempering small parts to the large equipments, the loads in which necessitate mechanical charging and discharging. All types are available although the construction of the various types differs in various respects. Some of the batch type furnaces have already been noted, but additional examples can be conveniently referred to in this section.

The use of vertical furnaces is gaining popularity for many components on two main grounds. Firstly, long slender parts, such as camshafts, torsion bars and similar components, are less likely to distort if carried vertically when heated for hardening as it avoids lifting the components from the hearth when they are at temperature. Secondly, such articles cannot be discharged into the quench tank in the same way that small parts can be dropped in, and if heated horizontally, must be removed from the furnace and quenched one by one. Not only does this take a considerable time if there is a full charge in the furnace, so reducing the output of the furnace, but also through the necessity of opening the door many times, the heat losses from the furnace are increased and the running costs thereby cannot be kept to a minimum. By the use of vertical furnaces a complete charge of components suspended from suitably designed heat-resisting alloy jigs may be removed from the furnace in one operation and quenched effectively as a complete charge.



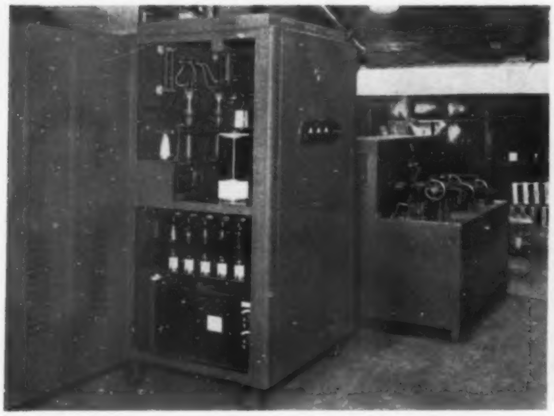
Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 14.—A box type toolroom tempering furnace using the "Cyclone" convection heating principle.

Fig. 12 shows a general view of an installation, by WILD-BARFIELD ELECTRIC FURNACES, LTD., of vertical hardening and tempering furnaces for the heat-treatment of automobile components. Chequer plating over the floor has been removed to give some idea of the depth and layout of such an installation, the space beneath the plating providing accommodation for the furnace transformers. Some of the jigs can be seen in the foreground. Interesting equipment by BRITISH FURNACES, LTD., for hardening solid high-speed steel knives, is shown in Fig. 13. It consists of two towns' gas-fired atmosphere-controlled muffle furnaces. The high temperature furnace has a muffle 12 in. wide by 4 ft. 3½ in. long by 5½ in. high to the spring of the arch, whilst the pre-heat furnace has a muffle 15¾ in. wide by 4 ft. 3½ in long. by 5½ in. high to the spring of the arch. Each furnace is heated by automatic proportioning low pressure gas and air burner equipment, the air pressure

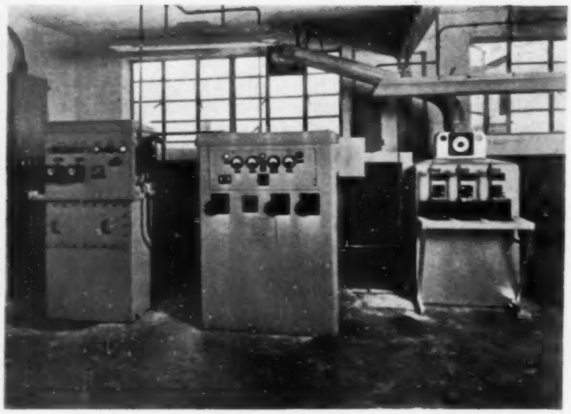
Courtesy of British Furnaces Ltd.

Fig. 13.—High temperature equipment for hardening high speed steel knives.



Courtesy of Metalectric Furnaces, Ltd.

Fig. 15.—" Thermonic " high frequency generating equipment with the work table on the right.



Courtesy of Wild-Barfield Electric Furnaces Ltd.

Fig. 16.—Radio frequency generator and multi-point induction brazing bench.

required being 1 lb./sq. in., with towns' gas at mains pressure. Mounted separately between the two furnaces is the special atmosphere preparation unit which supplies a protective atmosphere to both muffles. The principle of operation of this plant in producing the special atmosphere gas involves the addition of small quantities of unburnt towns' gas to the dehydrated products of complete combustion of towns' gas. This special gas is then piped to each muffle, and, having filled the muffle, sets up a slight positive pressure within the muffle, preventing ingress of air. The furnaces' temperatures are controlled by two indicating control pyrometers operating motorised valves on the burner equipment of each furnace.

The knives are first placed in the pre-heat muffle and raised to a temperature of approximately 900° C. They are then removed and immediately placed in the high temperature muffle at a temperature of 1,350° C., or thereabout, according to the steel specification. The knives are then withdrawn from the furnace and allowed to air-cool in a hydraulic press which ensures their flatness. Fig. 13 shows these two furnaces with the press on the left. The maximum length of knives being treated by these furnaces is 42 in.

The Efco-Lindberg system of air heating is another interesting development to be applied to both large and small heat treatment furnaces. The Electric Resistance Furnace Co., Ltd. are building a number of large plants for aluminium work, while a considerable number of smaller units have been installed, in which this system has been adopted. With this system heated air is drawn from the combustion chamber and forced at high velocity through the work, heating each piece uniformly and accurately. Radiant heat, which is believed to cause distortion, is completely eliminated. A standard box type tool room tempering furnace is shown in Fig. 14 in which the " Cyclone " convection heating principle is applied. Most of these furnaces are gas fired although a number are also engineered for either oil or electric heating.

Furnaces designed to apply " Cyclone " heating principle with temperatures up to 950° C. have equal heating and control accuracy within that range. This heating principle, with its wide temperature range, combines a hardening, normalising, annealing, tempering, and nitriding furnace into one, making it a highly flexible unit for the small or medium heat treating shop as well as a heavy production unit for the large shop when put to work on one type of job. It provides fast, uniform heating of heavy loads, eliminates distortion, and increases production.

Induction Heating

The applications of induction heating for heat-treatment and kindred operations continue to grow and during the recent year considerable developments have taken place. Whilst equipment operating at frequencies up to 10,000 cycles per second is employed mainly for melting and " through " heating, as for example for forging, in general surface hardening is carried out at frequencies from 250,000 cycles per second and upwards. Such frequencies are also used for soldering and brazing operations and the ability to localise the heating effect offers very material advantages in the production of many components which by other methods would have to be heated all over.

The rapid increase in tractor and ancillary farming implement production to combat the present world food crisis, has caused production engineers to apply this most modern form of heat treatment to their many problems. The manufacture of ploughs had to be speeded up, and for the hardening of furrow stub axles, high frequency induction heating equipment has been installed at a large Midland engineering works by Metalectric Furnaces, Ltd.

In this particular case, a throughput of 1,000 separate surface hardening operations was required each day, and the " Ther-monic " Model 1070, having an input of 38 kva. and an output of 20 kw., or 1,070 B.th.u's per minute at a nominal frequency of 376,000 cycles per second, was chosen. This generator, with its worktable on the right, is shown in Fig. 15. The worktable is of the two-position type. Two identical induction coil systems are provided. with a central high voltage change-over switch. Around each set of coils, a loading device for the components is built up, combined with a water spray quenching system. Vices are incorporated to hold each component in position, and a motor-operated cam system, with quick return for discharge, progresses them through the induction coils. The speed is regulated to provide the required surface temperature, and the

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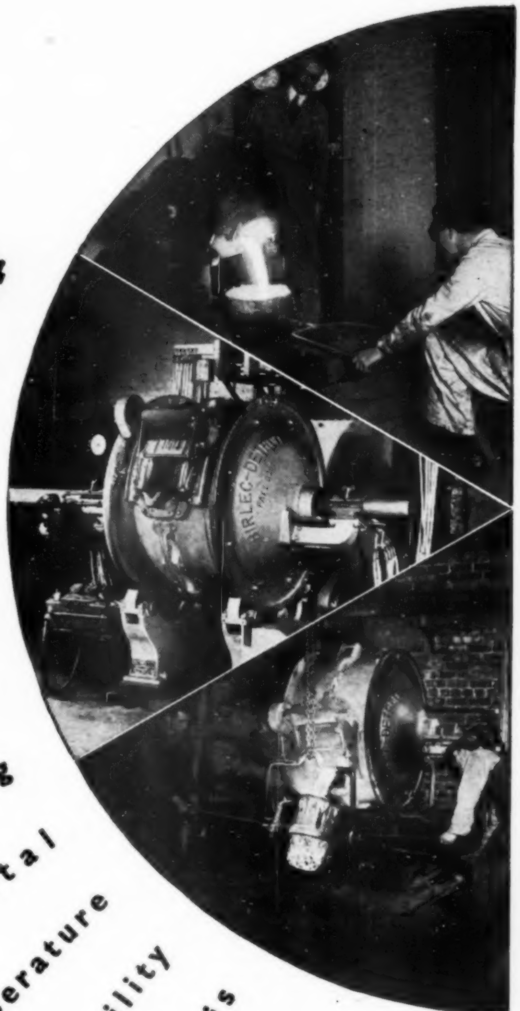

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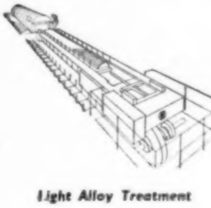
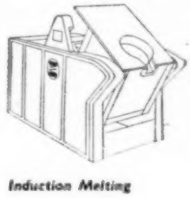
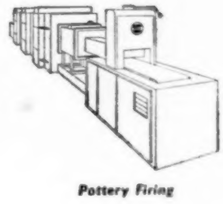


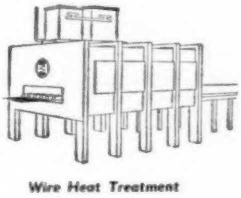
Light Alloy Treatment



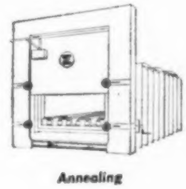
Induction Melting



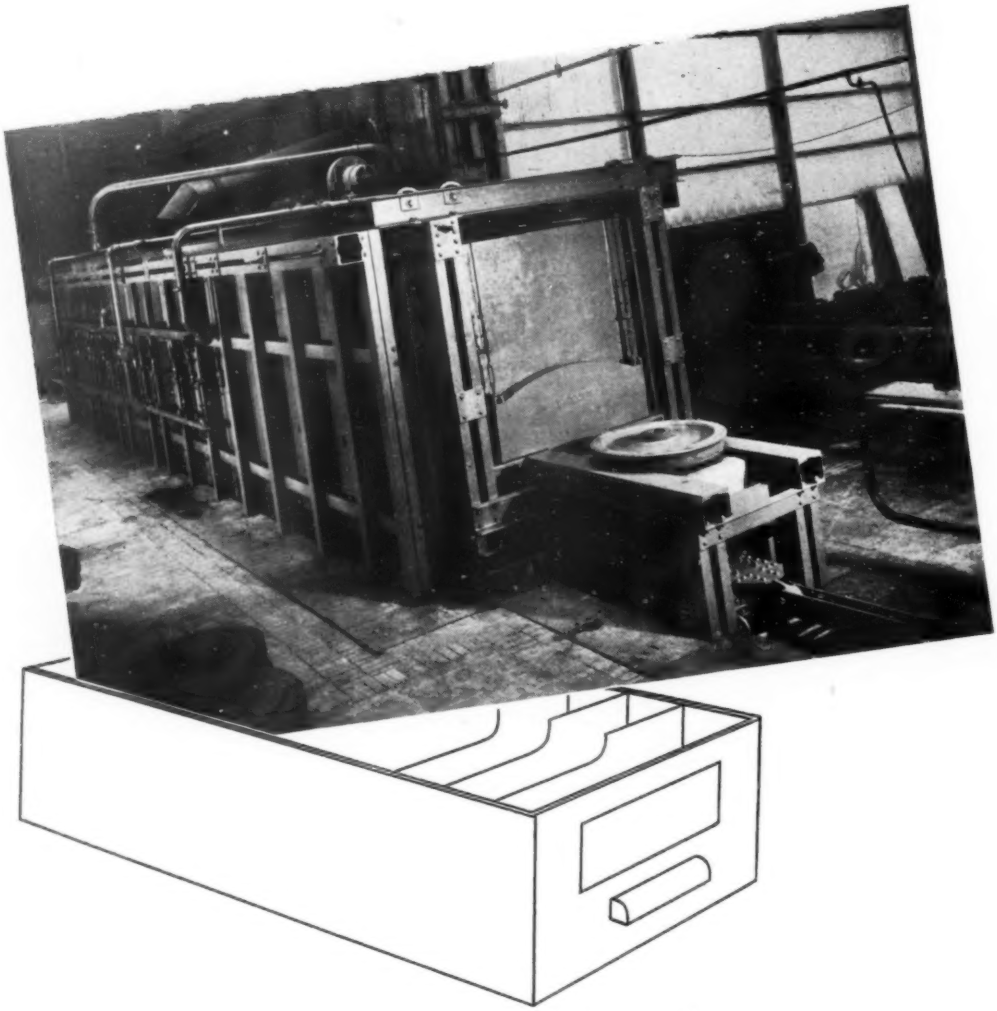
Pottery Firing



Wire Heat Treatment



Annealing



This is a Moving Hearth Furnace fired by Coke-Oven Gas and designed for the heat treatment of wheels before water spraying and tempering.

The furnace is 49 ft. 6 in. long and takes wheels up to 48 in. dia., weighing 1,350 lbs. each.

The Moving Hearth is carried on a series of lifting units connected by push-pull rods, and the cycle of lifting, charging, lowering, and return is hydraulically operated and completely automatic.

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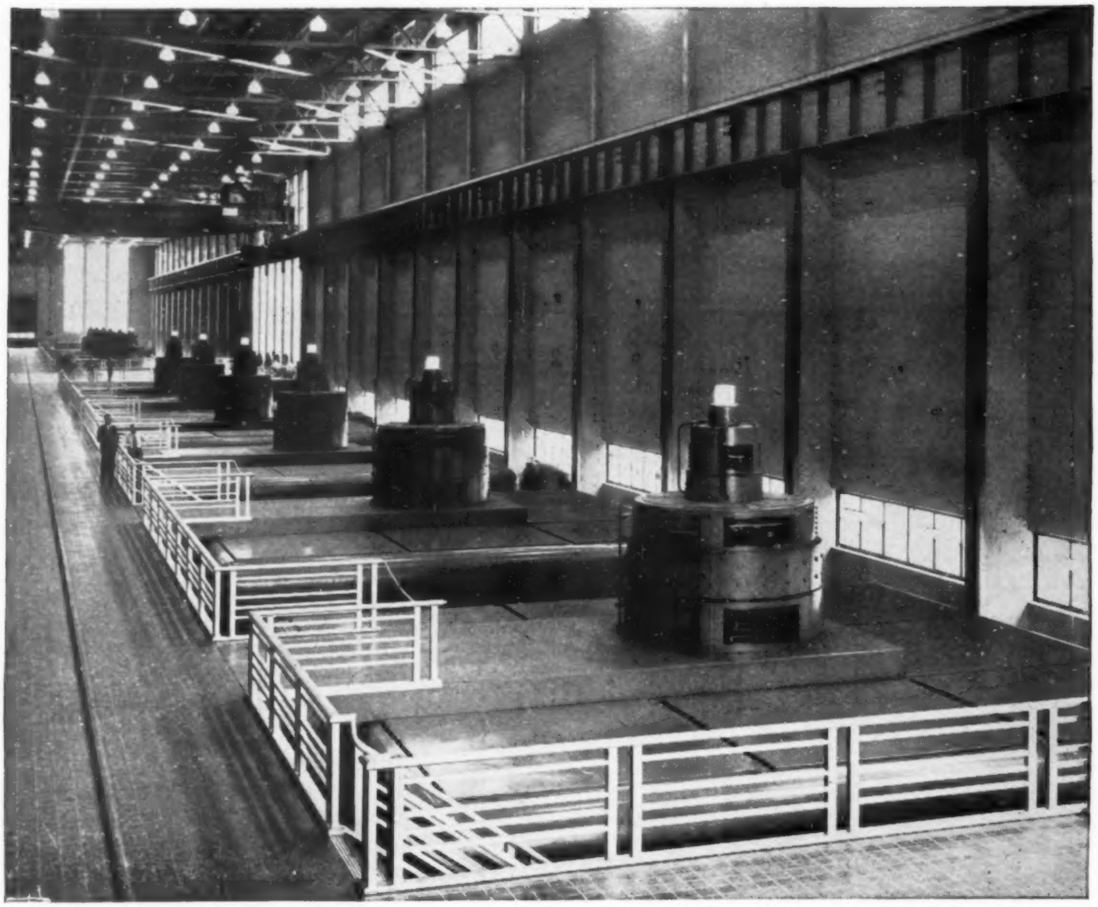

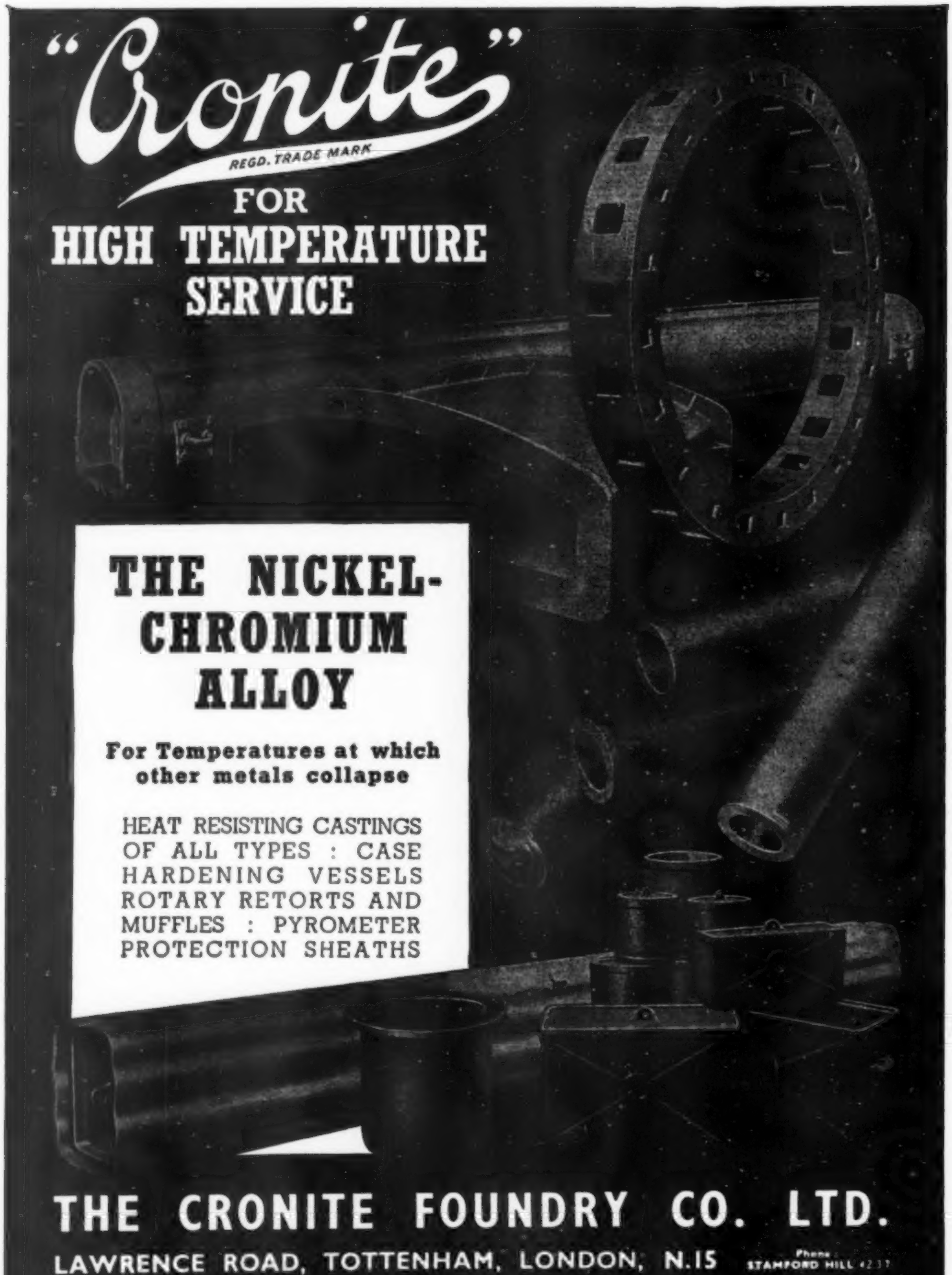
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spray quench system, embodying solenoid valves, is entirely automatic. Whilst one pair of components is being processed on one side of the table, the other set of vices is being unloaded and re-loaded, and the operation of the high voltage switch, reverses the cycle.

There are many ways where selective surface hardening by this method, has, in quantity production, supplanted more conventional forms of heat-treatment, and the above only illustrates a typical application.

A typical installation for brazing and silver soldering components is shown in Fig. 16. It is a Ferranti-Wild-Barfield production and comprises a radio frequency generator and a multi-station brazing bench. Such a brazing bench is of advantage where the heating cycle forms only a small part of the total cycle, for an "overlap" can be arranged whereby one station can be loading, one heating and one cooling or unloading simultaneously. Under these circumstances, a much better load factor on the R.F. generator is possible, with consequent reductions in operating costs. It is interesting to note that the R.F. oscillator shown, and all those in the Ferranti-Wild-Barfield range from 2 kw. to 60 kw. employ air-cooled silica enclosed repairable oscillator valves. The elimination of water-cooled valves avoids the use of distilled water and the associated complications of circulating pumps and heat exchangers which are normally otherwise required. The fact that the valves are repairable contributes substantially to reductions in operating costs for the repair charge is only about 50% of the price of a new valve. The life of these valves is long, but is not everlasting and such a reduction in maintenance costs is important.

A further application is in dielectric heating which is being used for the drying of synthetic resin-bonded cores in foundries. One of the main time consuming operations in foundries is the drying of the cores compounded from sand, binders, linseed oil, etc., this being due to the poor thermal conductivity of the cores and the time factor required for the polymerisation of the linseed oil. The introduction of synthetic bonded cores has reduced greatly this time factor, as well as giving better cores from all points of view. Two general production methods can be employed :—

(a) *Batch type.*—Where the output consists of a wide variety of small cores, a batch type equipment is to be preferred and in such cases the operator loads and unloads the equipment.

(b) *Continuous types.*—If quantity production of similar cores is desired then the continuous plants are better employed. The cores are placed on the belt of the continuous plant in the given state and emerge fully dried at the exit end.

It is difficult to give precise drying times as this is a function of size and shape, but on the average it may be taken that by employing synthetic resin-bonded cores and dielectric heating as opposed to linseed oil bonded cores and normal stove drying a saving in time of the order of 80–90% can be achieved.

Conclusion

It has only been possible to present a few typical examples of heat-treatment equipment, a number of interesting installations have been unavoidably omitted because detailed information concerning them is not available, but the examples briefly noted indicate that furnace manufacturers are continuing progressive trends in design. It will have been noted that more and more attention is being directed to maintaining control of the atmosphere within furnaces and to methods for ensuring uniformity of temperature in the parts being treated.

In the past it has frequently been said that the art of heat treating did not progress at the same rate as the science of heat-treatment, and the results obtained in the shop often fell short of the standard that had been shown to be possible in the laboratory. There will always be a time-lag between the progress achieved in the laboratory and its successful application in the workshop, and the art of heat treating is not an exception to the general rule, but there is less reason for such charges to-day, because of the facilities for accuracy which modern heat-treatment plant and equipment give, and, where proper equipment is available, it is probable that this time-lag is much less than that in which any other laboratory development is involved.

Much depends upon the equipment installed in the heat-treatment shop ; furnaces and equipment of a very high order are available which can reasonably be classed as precision tools. With the aid of these modern appliances, heat-treaters have greatly advanced in their art, but, even with the best equipment, the increasing demand for materials possessing widely different properties calls for operators of considerable skill and experience.

Aluminium Pots and Pans

A Factory With An Outstanding Output

Eight main production lines, ten accessory lines, forty power presses and 360 other machines, are installed in a factory and operated by about 700 men and women for the mass production of household utensils in aluminium. Annual output of such articles as kettles, teapots, etc., have reached phenomenal figures and the demand for them continues unabated.

TWO million kettles, a million and a quarter teapots, one million one hundred and fifty thousand stewpans, half a million coffee percolators and as many hot water bottles—these were last year's output figures of a factory at Neath, which is the largest works in Britain devoted solely to the manufacture of household utensils of this kind. They slide off eight main production lines at the rate of one every eight seconds—which means, when all are working, a rate of one a second. In addition to the eight main production lines there are ten accessories lines. Output figures from these are even more phenomenal. Last year, three million spouts were produced ; nearly five million rivets, knobs, clips, strainers and other parts are made every month.

This factory, which thinks and works in millions is at Millands. On its 80,000 sq. ft. of concrete, 700 men and girls, helped by forty power presses and 360 other machines, are occupied in a variety of cutting, piercing,

polishing, spinning, inspecting and packaging processes. They work in three shifts over a five-day week. In charge of this enterprise is Mr. F. E. Barron, a mass production engineer with war-time experience of mass producing shell cases and other munition parts, who four years ago was invited by the directors of the Midland Metal Spinning Co. Ltd., of Wolverhampton, to mass produce aluminium domestic utensils. This firm, makers of " Tower Brand " hollow ware, was established in 1919 and to-day controls a number of factories.

In August, 1945, a Government standard factory, adapted and designed for flow-line production methods, was completed at Neath, and Mr. Barron took charge to put his mass production ideas into practice. By Christmas, 1945, nearly 500 workers were employed. In the early months production was concentrated on stewpans and a rate of 450,000 a month, set in 1945, was maintained throughout 1946 and early 1947. During 1946 a kettle line was added, and kettles were produced at the rate of 50,000 a week throughout 1947. By the end of 1947 teapots were being made at the rate of 2,000,000 a year. The manufacture of electric hot-plate utensils, hot water bottles and coffee percolators followed, and last year whistle kettles were added. These are probably the biggest output figures, over the range of products, from any one factory in the world. They have been reached by the development of mass production methods to a high pitch of efficiency.

As would be expected in such a factory, walking fetching and carrying have been eliminated as far as possible to allow each member of a team to concentrate on a particular operation. Each operator's machine is located alongside a conveyer, which carries the product from its starting point to the packing department. The operator is fed with rivets, handles, knobs or whatever is required. The completed article is taken direct from the conveyer and finished, wrapped and packed in cases or crates, for immediate despatch.

An inspection staff examines every finished utensil and most of the components. With a permanent emphasis on quality, the standard has risen steadily and this is regarded as one of the reasons why the factory is now fully engaged with substantial home and export orders. Six in ten of the kettles, half the teapots and 40% of the stewpans are sent abroad—to 83 different countries.

One of the management's chief objects has been to keep labour contented and fully employed. This has necessitated the use of a large amount of space to absorb production in " easy " periods and from which stock could be withdrawn in " rush " periods. For this reason the firm took over recently a 76,000 sq. ft. factory at Hirwaun, but so great has been demand this year so far that little use has been made of it. January was an all-time record for home and export sales. Tentative figures for 1948 indicate that the company supplied almost 30% of all exports of hollow ware from its factories at Neath and Wolverhampton, although 200 other firms in Britain make similar products.

When the factory came to Neath, available labour was entirely unused to mass production methods of aluminium hollow ware and an early problem was the training of operatives. It became necessary to create a high-speed production outlook. The plan adopted was to create a production team mainly of girls with men for the heavier operations. Team spirit was fostered, and to-day there is keen competition between one team and another for the highest output of quality work.

An innovation has been the fixing of a large clock-like indicator above each production line. A blue hand indicates the highest output ever reached on a shift. A red hand shows the progress of a particular team hour by hour. All operatives can see the progress they are making and, if towards the end of a shift there appears to be a prospect of the previous highest output being overtaken, a spurt is made to see if a new high record can be set up. This happens only occasionally and the normal production rate of most utensils is between 4/5,000 per shift. A top figure of over 5,000 in one shift—the record so far—is considered " a terrific team effort."

The labour force to-day is about 700 employees—65% women, 35% men—the majority of whom are in established teams. There is the kettle team, the teapot team, the stewpan team, the lid team, and so on. Maintaining output from such highly geared and organised teams is not easy and production is peculiarly susceptible to absenteeism. Various methods have been tried to minimise its effect and the latest plan is the creation of a " pool " of crack operators to be available at any moment. When a member of a regular team is absent, a skilled operative from the " Pool " is drafted immediately to the line so that production is not held up. The management is also considering introducing special uniforms for these " ace " operatives.

Believing in the closest co-operation between management and workers, Mr. Barron discusses problems with individual operators and trade union representatives. He considers that the best way out of most difficulties or of discussing new wage schemes is for everyone to get together in the factory canteen and " flog " it out. An output bonus scheme is in operation and as much as 30/- for females and 50/- for males may be earned over and above the basic weekly rates. Simple and often humorous slogans on the walls inform operatives how they will benefit by good quality high outputs.

Consideration was recently given to taking another factory at Neath Abbey for the manufacture of many accessories now imported from Wolverhampton. This project has been turned down in favour of a big extension at the Millands Factory.

New President of the Council of the Aluminium Development Association.

At the recent Annual General Meeting of the Aluminium Development Association, Mr. Kenneth Hall was elected as the new President of the Council. Mr. Hall is Managing Director of Northern Aluminium Company, Ltd., and a Director of Aluminium Laboratories Limited.

Mr. Hall has been associated with Aluminium Limited of Canada for over twenty years, and came to this country in 1936 as Manager of Northern Aluminium Company's Birmingham Works, where he installed the original forging equipment, including the first large air hammer of its kind to be used in the British light alloy industry.

In 1938 Mr. Hall became Managing Director of the newly-formed Indian Aluminium Company, Ltd., and during the war was responsible for the erection of aluminium reduction works, alumina works and rolling mills, these being the first works to produce and fabricate virgin aluminium in that country. Mr. Hall returned to England in 1946 to assume the position of Managing Director of Northern Aluminium Company, Ltd.

The British Industries Fair

Continued from page 28

Small Tools

EDGAR ALLEN & CO., LTD. will show, on Stand D.630, a comprehensive display of small tools for engineers, including toolholder bits; Stag Major Superweld butt-welded tools for lathes, planers, shapers, etc.; precision-ground form tools, both solid and butt-welded; tungsten carbide standard tools and tips; and Athyweld atomic hydrogen-welded tools for a wide range of purposes. Particularly interesting will be a display of Athyweld wood-working machine knives, in which maximum safety is obtainable owing to the fact that the cutting edge will only splinter, and not disintegrate with possible danger to the operator, when something goes wrong with the machine or the cutting operation. Other applications of the deposit welding Athyweld process to a wide range of tools, such as knurling tools, rubber cutters, hot shear blades, etc., will be shown.

A comprehensive display of dies of the most intricate character made from Edgar Allen Double Six and K.9 steels will be shown, while of interest to plastics manufacturers will be a series of moulds, hobs, etc., for the plastics industry, made from the range of Edgar Allen tool steels specially designed for the purpose.

As part of the ENGLISH STEEL CORPORATION's Stand D.623, there will be a display of engineers' small tools covering almost the entire range of this type of product.

"The Toughest Tools in the World" is the description given by MACROME, LTD. to their products, whose wide range will be exhibited on Stand D.746. The Macrome treatment, which can also be app ied to customers' tools, consists of a thermo-electrical process which imparts to the tools an added resistance to wear, fatigue and breakage with a consequent increased output per re-grind and *in toto*.

The recently produced Wimet documentary film on the technique in application of tungsten carbide turning tools will be on exhibition on the WICKMAN Stand D.416. The film deals with most aspects of carbide tooling for normal workshop use and after describing the manufacturing processes involved in the production of the material, shows at length the principles behind the design of Wimet carbide tools and the effect of cutting rakes and angles on metal removal capacity and tool life. Cutting speeds, feeds and depth of cut are simply explained and a comparison of production with Wimet tooling and high speed steel tooling clearly shows the economic advantages of Wimet tungsten carbide tools. The film emphasises the need for correct and timely servicing of tools and deals with the methods recommended for re-grinding and lapping.

Instructors from the Wimet School will be in attendance on the Wickman stand during the exhibition to advise on technical problems associated with carbide tooling.

The increasing adoption of Wimet carbide tools by industry generally is reflected in the wide range of tooling applications on show. Pottery, textiles, building, mining, plastics and automotive servicing are among the many industries represented in a comprehensive display and demonstration of cutting tools in addition to the well-known range of Wimet tools for the engineering and sheet metal industries.

On Stand D.402, DELORO STELLITE, LTD. will be exhibiting for the first time a range of precision cast Stellite dies for the hot extrusion of copper and zinc base alloys. A variety of other precision cast components such as cams, dies, high pressure air valves, etc., will also be shown. A feature of the display is that all Deloro Stellite products i.e., Stellite cutting metal, hard-facing rod and castings are now produced in England as well as in Canada. A range of Stellite cutting tools for turning, milling, planing and woodcutting will be displayed. A number of Stellite hardfaced components will also be on view, including such items as steam and chemical valves, punches and dies, and various other components.

Demonstrations of hardfacing with Stellite rod will be given throughout the exhibition, and visitors are cordially invited to bring their own small components for processing on the stand.

FIRTH BROWN TOOLS, LTD. on Stand D.627 will show a comprehensive range of engineers' cutting tools, comprising:—High speed steel twist drills; reamers; milling cutters; lathe tools; taps and dies; Insto metal cutting saws; engineers' files; carbide tipped saws for cutting plastic moulds; and carbide tipped tools and dies. The high frequency method of brazing Mitia carbide tipped tools will also be shown.

Furnaces

A number of interesting demonstrations will be staged on the BRITISH GAS COUNCIL's Stand, C.619/518, of which two are of direct interest in connection with metals. In the first, staged by the CITY OF BIRMINGHAM GAS DEPARTMENT in conjunction with a leading firm of tube makers, a small gas-fired furnace, capable of temperatures in excess of 1,500° C., is used for heating tubes in the production line, the temperature attained depending on the rate of travel. The method is said to be applicable to bars also. The second development, demonstrated by the SOUTH METROPOLITAN GAS CO., is the use of gas for immersion heating. This is now being used in the melting of soft metals.

Amongst the large number of gas appliances exhibited are the following: Lead-melting furnace, by JOHN F. ASKAM, LTD.; high-speed steel hardening furnace by BRAYSHAW FURNACES & TOOLS, LTD., with temperature measuring control equipment by ELECTROFLO METERS CO., LTD.; salt bath furnace by BRAYSHAWS with temperature measuring equipment by ELLIOTT BROS. (LONDON), LTD.; "Conjecto" air-blast oven furnace by BRITISH FURNACES, LTD., with ELECTROFLO temperature measuring and control equipment; assay furnace by THE GAS LIGHT AND COKE CO.; oven furnace by THE INCANDESCENT HEAT CO., LTD., with temperature indicating equipment by METALECTRIC FURNACES, LTD.; and a forge furnace by THERMIC EQUIPMENT & ENGINEERING CO., LTD., with temperature indicating equipment by ETHER, LTD.

A particularly interesting exhibit of BIRLEC, LTD. on Stand D.509/406 is a fully automatic, rotary-drum type furnace, designed for carburising small parts in quantity. Charging, tumbling of the charge to ensure complete uniformity of treatment, and discharge direct into the quench tank are all made automatic, remote-controlled operations, so that one attendant can supervise the working of a battery of such furnaces without difficulty and with complete regularity of output and uniformity of results. This type of furnace can be used also for carburising in compound, if desired, without involving packing of the work in boxes.

Courtesy of The Electric Resistance Furnace Co., Ltd.

High temperature sintering unit.

Another type of specialised Birlec heat-treatment equipment, is exemplified by an automatic high-frequency induction heating unit, for surface hardening automobile gear-box shafts, which will be demonstrated on the stand. The equipment represents a type which is adaptable to the hardening of a variety of shafts and other long parts of uniform section and is designed to be installed directly in the production machine line.

Other Birlec equipment, ranging from large steel-melting furnaces to bright annealing and other copper-brazing equipment, will be represented by models and photographic displays and by samples of typical furnace products.

Stand C.321/220 is shared by WILD-BARFIELD ELECTRIC FURNACES, LTD. and G. W. B. ELECTRIC FURNACES, LTD.

Equipments to be exhibited by the former are mostly for toolroom use, and include the TRT 1010 toolroom tempering furnace for temperatures up to 650° C. The furnace embodies forced air circulation and, with special equipment, can be used for nitriding. Horizontal batch type furnaces will be represented by a "Workshop" furnace complete with built-in Paragen burner. The well-known E.S.B. Minor electrode salt bath will be shown with its alternative metal and refractory pots. Laboratory electric muffles, samples of gas carburised work—carried out using the Wild-Barfield prepared towns' gas process—and exhibits illustrating the advantage of the Paragen system of atmosphere control, complete the furnace exhibits. Radio frequency heating is covered by a Ferranti-Wild-Barfield Model 2 BDP Dielectric set and a Model 2 AI induction heating set together with samples of work illustrating both methods.

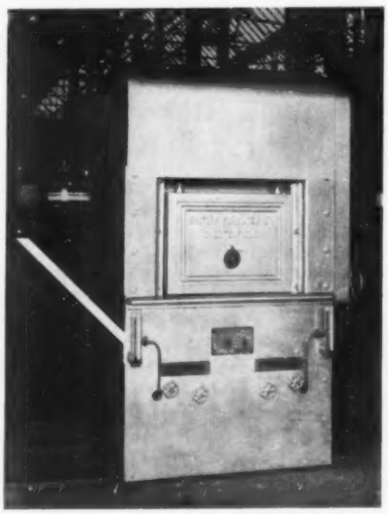
Furnaces manufactured by G. W. B. ELECTRIC FURNACES, LTD. being too large to exhibit, representative installations will be shown by means of photographic enlargements. Autolec boilers of various sizes will be shown in operation and a model of an Eternite case-hardening compound cleaner will also be exhibited.

A new radio-frequency induction heating generator, embodying the most recent advances in engineering technique in the electronic field, is employed in the Efco-Tocco R.F. induction hardening equipment shown by the ELECTRIC FURNACE CO., LTD. on Stand C.611. In the present instance it is coupled to a progressive hardening station for lawn-mower cylinder cutters and bottom blades. This type of heater station can be used for a number of hardening applications involving the movement of the inductor relative to the work—e.g., rocker shafts, small camshafts, etc. The progressive fixture is driven by a D.C. motor with an electronic controller. The speed of the movement can be predetermined, and can, if required, be altered during the stroke. It can be stopped in any position for a specified time, if intermittent hardening is required, and a fast return speed is provided. The quench can be controlled for any required period by the timer incorporated in the rectifier, and can be continuous or intermittent as desired.

On the same stand the associated ELECTRIC RESISTANCE FURNACE CO., LTD. are exhibiting two furnaces of modern design which have not previously been shown in this country.

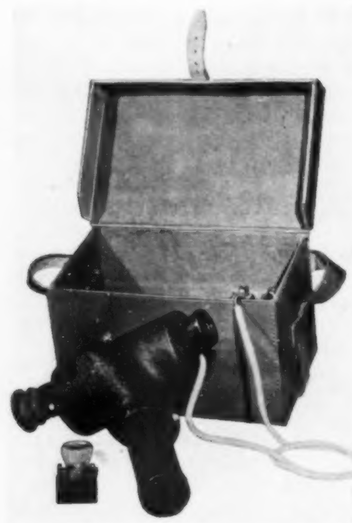
The first is the Efco-Lindberg box-type cyclone furnace using the famous Lindberg cyclone forced convection principle of heating and recirculating the air. As the fan and heater are located in a chamber away from the furnace, there is no possibility of accidental damage to the parts and elements can be replaced without disturbing or cooling the charge. The furnace is available in two temperature ranges up to 450°/700° C. This system of heating is also applicable to vertical furnaces and many of this type are now being built.

The other unit is a high temperature sintering unit for use up to temperatures of 1,700° C. This furnace has



Courtesy of British Furnaces, Ltd.

"Conjecto" gas-fired oven furnace.



Courtesy of Elliott Brothers (London), Ltd.

Elliott optical pyrometer with carrying case and spare lamp.

a molybdenum winding operating in a hydrogen atmosphere and is available in 1–5 in. dia. tube sizes. Rectangular tube furnaces are also available. Due to the recent rapid advance in powder metallurgy technique a considerable number of such furnaces are being installed in this country and abroad.

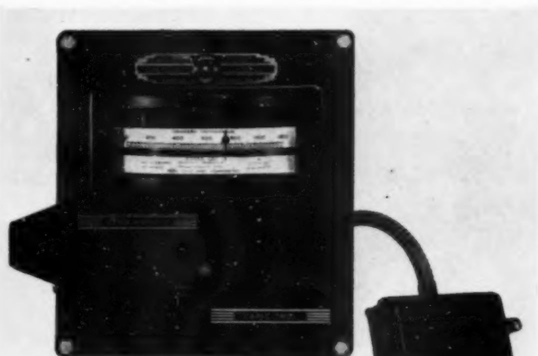
It is impossible in the space available to show many of the furnaces which they build for heat-treatment, but to demonstrate the wide variety of work handled, samples, such as copper brazed, bright annealed, bright hardened, carburised, and salt descaled parts will be shown on the stand.

A novel design has been introduced in the Stand (C.727 and 626) of the Incandescent Heat Group of Companies, comprising the Incandescent Heat Co., Ltd., Metalectric Furnaces, Ltd., Controlled Heat and Air, Ltd., Selas Gas and Engineering Co., Ltd., and Metal Porcelains, Ltd. Four conveyers, each carrying about a dozen photographs of the various plants manufactured by the different companies, radiate from a central office towards the corners. Included in the illustrations will be various types of melting and heat-treatment furnaces, heated by solid fuel, gas, oil and electricity; low temperature stoves for paint and enamel; core ovens; burners and valves; laboratory furnaces; and vitreous enamel frits, oxides, etc.

A new plant now being manufactured by the Incandescent Heat Co., Ltd., and which will attract great interest, is the Drever gas-tight continuous strip annealing process for the economical high-speed bright annealing of high, medium and low carbon steels, nickel and nickel alloys, beryllium copper and other copper alloys, etc., and the clean annealing of silicon steel and brass. These plants are suitable for either electrical heating or radiant tube firing and can be supplied for outputs ranging from 100 lb. to 15 tons per hour.

Another new attractive process is the Lithanol vapour carburising system. This method entirely eliminates boxes, compounds and subsequent labour charges and obtains the required case depth in half the times required by the pack method.

The General Chemicals Division of Imperial Chemical Industries, Ltd., are featuring on Stand D.315/212 their metal degreasing service (embracing the use of trichlorethylene, alkalis and emulsions) and their heat-treatment service for molten salt baths.



Courtesy of Ether, Ltd.

Ether-Wheelco "Capacitrol" electronically operated temperature controller. Type 221.

Amongst the several metal degreasing plants on view will be an electrically-heated bench model for handling delicate instrument parts, a medium-size plant to work on a single phase A.C. supply, and a totally enclosed continuous plant (with automatic ventilation) for degreasing intricately-shaped articles. All these plants will be installed for normal working on the stand.

In addition to featuring the various "Cassel" heat-treatment salts and processes, the exhibits include a selection of standard "Cassel" salt bath furnaces of an unusually wide range of sizes (the largest shown has a pot 72 in. deep). Of particular interest is a totally enclosed automatic carburising furnace.

Temperature Measurement and Control

The importance of accurate temperature measurement and reliable and efficient control is paramount in modern heat treatment where, in many cases, the permissible tolerance on temperature is quite small.

Ether, Ltd. are exhibiting on Stand C.700 a range of temperature measurement, and control instruments which embody the latest technique in design, and construction. These comprise instruments operated on the electronic principle, foremost amongst which are the "Capacitrol," and "Multronic" indicating controllers, in which the electronic control circuit gives instantaneous response to changes of temperature. Several types of these instruments will be shown in operation arranged for control of gas, oil, and electric furnaces, and apparatus.

The Ether "Wide-Strip" Potentiometer Recorder will be exhibited in two forms: as an electronically-operated instrument for high-speed work, and as a mechanically operated instrument for normal speeds in excess of 45 seconds across the chart. This is arranged as a controlling recorder for on/off and fully proportional control. The "Indicorder" continuous chart recording instrument will be shown in several forms, the most novel being as a p/H recorder and controller. Mechanically operated indicating controllers of the chopper-bar type will also be shown in a large number of applications, as on/off, 3 and 4 position, and full proportional control. In conjunction with the above instruments a range of operated valves will be displayed.

In addition to Ether's well-known portable molten metal pyrometer a special instrument for molten metal temperature up to 1,600° C. will be shown. For other high temperature work disappearing filament and total radiation pyrometers, suitable for the range 700°–2,200° C. will be exhibited. A wide range of thermocouples will be displayed, including surface contact couples with a rapid response—as little as 5–6 seconds giving a final reading.

On Stand D.503 (Elliott Bros. (London), Ltd.) the main feature will be five panels of flush type industrial indicating and recording instruments, representative of the wide range of equipment for which Elliott Bros. are famous. Included in the instruments so displayed are the new Elliott potentiometer recorder with magnetic inverter; the new Elliott 3-term pneumatic controller; CO_2 and $CO + H_2$ indicators; temperature indicators; and 2-point and 6-point recorders.

A most convincing demonstration of the accuracy and response of the Elliott remote indication and control system will be given by a small transmitter, operated by a knob, coupled to a 33 in. indicator above the stand.

The pyrometers shown will include an optical pyro-

Courtesy of Johnson, Matthey and Co., Ltd.

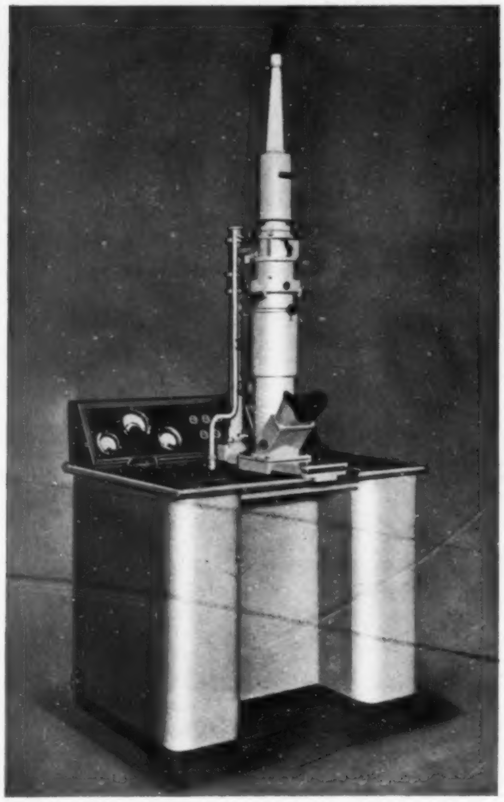
Reaction vessel of solid silver with cast iron jacket for the manufacture of corrosive medicinal intermediates.

meter outfit with two temperature ranges (800°–1,400° C. and 1,200°–2,200° C.); a portable total radiation pyrometer; a portable thermo-couple potentiometer; and a representative range of thermo-couple pyrometer stems. As the result of extensive research on magnetic amplification, standard magnetic amplifier units have been evolved and examples of applications demonstrated on the stand include a thermo-couple amplifier.

Whilst Electroflo Meters are not exhibiting themselves, the application of their temperature control equipment to an electric furnace will be shown on the Birlec stand and to a gas furnace on the British Furnaces exhibit on the British Gas Council's stand.

Precious Metals

The use of the precious metals in industry continues steadily in the fields where oxidation and corrosion resistance are of importance. The exhibits of Johnson, Matthey & Co., Ltd., on Stand D.100 are divided into seven main groups. For many years now the company have marketed the well-known Easy-flo low temperature brazing alloy or silver solder. This year's exhibits will include demonstrations of two new alloys, Easy-flo No. 2, which is cheaper and has a lower melting point than the original, and Easy-flo No. 3, specially developed for tool tip brazing. A wide range of resistance welding electrodes will be of interest to welding engineers and the exhibition of electrical contact alloys will include a large variety of types and materials. Fine drawn precision products in both precious metals and the more common materials will include wires in nickel-chromium, the various resistance alloys and the thermocouple alloys together with products, such as platinum gauze, made from them. The precision drawn tubes shown cover such types as instrument capillary tubes, pressure gauge elements, pointer tubes and nickel tubes for valve work. In the sheet metal section, emphasis is placed on the enormous range of materials available and on the composite materials such as bi-metal strip. The exhibits



The Metropolitan-Vickers EM.3 electron microscope.

will include pressings and spinnings made in such materials. The last section, in which the exhibits are largely photographic, concerns the application of metals such as silver to chemical engineering.

Whilst perhaps best known in the precious metals field, the exhibits of The Sheffield Smelting Co., Ltd., on Stand D.731 will include exhibits demonstrating the activities of the company in the non-ferrous casting field. These comprise castings in aluminium, brass, bronze and gun metal, together with aluminium alloy die castings and ingots in bronze, gun metal, cupro-nickel, nickel silver, etc.

On the precious metals side will be displayed the "Thessco" range of silver solders and brazing rods together with special "Thessco" fluxes produced to suit the different melting ranges. A representative selection of fuse wires and tapes and electrical contacts made in pure metals and alloys, and from bi-metal strip will also be exhibited. For plating, "Thessco" quality anodes and plating salts will form another section of the stand, and a further section is devoted to the highest purity platinum, laboratory apparatus and salts of the precious metals. Of special interest in the thermo-couple section will be an exhibition of a special type of liquid steel immersion pyrometer made by T. Land and Sons, Ltd., of Sheffield. This unit is for use on H.F. induction furnaces and a similar larger unit is used for electric arc furnace, open hearth furnace or ladle metal temperatures.

Miscellaneous Metallurgical Products

It would be impossible, in the available space, to present a complete list of the products of MUREX, LTD., who are exhibiting on Stand D.709. A very wide range of metals, non-ferrous and ferrous alloys and salts of tungsten, molybdenum and vanadium are produced at their Rainham works, and a representative collection of these will be on view. Included in the products are addition alloys used in the manufacture of steel, copper and aluminium alloys; carbides of tungsten, titanium, molybdenum and vanadium; various metal powders, including tungsten, molybdenum and cobalt; and "Eel" anti-friction metal, a nickel-hardened lead-base bearing metal approved by Lloyds. Aluminium-nickel-cobalt permanent magnets, produced by powder metallurgy methods, will also be shown. As it is not possible to fabricate these alloys by rolling or forging, this application of powder metallurgy has greatly expanded the field of application of these powerful magnetic materials.

Various applications of the "Thermit" process, used for welding and for making steel castings, will be displayed including samples taken from sections of railway and tram tracks, welded by means of the "Thermit" process; photographs illustrating the repair of large shafts, pinions and millhousings and the repair of tramway tracks without interruption to traffic; and a number of small castings made by the process, together with photographs of the technique of production. Small steel castings by the Thermit process have saved many production hours as they can be produced in a matter of minutes once the mould is made.

Two types of iron powder are marketed by GEORGE COHEN, SONS & CO., LTD., Stand D.604, under the trade name "Sintrex." The electrolytic iron powder is of very high purity and particularly suited to applications in the electrical field, and for sintered permanent magnets and in the manufacture of diamond impregnated tools. The grey cast iron powder is freed from all dirt, dust and grease, and as much graphite as possible. It is used in the chemical industry and for concrete floor hardening.

Visitors interested in the use of ferro-alloys and titanium containing aluminium alloy addition agents will find much of interest on the stand of MINWORTH METALS, LTD. (Stand D.153. Samples will be exhibited of the company's products which include ferro-alloys of titanium, molybdenum, tungsten, vanadium and manganese; pure chromium and manganese; titanium-copper hardener; and a wide range titanium containing master alloys for addition to aluminium.

Machine Tools

Although the machine tool trade in general is not represented at the Fair, there are a number of exhibits of interest to the metal-working industry.

On Stand D.603, E. W. BLISS (England) LTD., are showing a number of drawing and stamping presses. Single crank toggle presses are widely used in the manufacture of drawn metal articles, ranging in size from toy drinking cups to domestic washing machine tubs. The No. 3½C press, which may be seen in operation, is of one piece steel frame design. The capacity of the plunger is 110 tons and that of the blankholder 80 tons at the bottom of stroke, the actual maximum combined load being about 135 tons.

The 600 series of high production presses was developed by the parent company in America to accommodate a growing demand for press equipment to produce large quantities of stampings requiring comparatively short strokes. These automatic presses are now extensively used by the manufacturers of automobiles, electrical equipment and household utilities. On view will be the No. 630 press which has a maximum capacity of 45 tons; rating for fine blanking dies 30 tons; a standard stroke of 1 in. and a maximum of 3 in.; a 6½ in. shut height and normally operates from 100–300 strokes per minute.

No. 8 and 12 bench power presses, which enjoy wide popularity among small press users will also be seen.

TAYLOR AND CHALLEN LTD., on Stand D.415, will be displaying a number of metal working presses together with illustrations. The machines comprise an automatic coining press No. 581, as supplied to British, Colonial and Foreign Mints; a size 3½ double-geared drawing press, for the production of seamless articles from blanks of steel, brass, aluminium, etc; a 370 geared press, fitted with automatic dial feed; a 1632 press, fitted with automatic roll feed, with balanced slide and scrap winder, and tools for steel pens; and an automatic press No. 1732, with grip and transfer feed, for the production of brass parts, such as electric lamp holders from strip material.

Well known as designers and builders of hydraulic presses and hot and cold rolling mills for the steel and non-ferrous industries, together with auxiliary equipment, THE LOEWY ENGINEERING CO., LTD. (Stand D.132) will display a number of photographs and drawings of plant recently manufactured, including machinery for the United Kingdom, South Africa, Sweden and France.

Press brakes and drop stamps are also shown on the stand of THOS W. WARD, LTD. (D.745 and D. Outdoor), whilst the 600 GROUP OF COMPANIES (Stands D.604 and D. Outdoor) include in their display the Coborn-Wadley Type D.E.P.S. 24 universal punching, shearing, cropping and notching machine; the Coborn Type No. 20 front inclinable press; and the Coborn 42 in. gap hand-operated panel wheeling and raising machine.

In the toolroom, and for the cutting of test pieces from forgings and castings, a bandsaw is an extremely useful piece of equipment. On Stand B.228, THE MIDLAND TOOL & SAW CO., LTD., are exhibiting a number of band-sawing, band-filing, and cut-off machines including a "Hyspeed" bandsaw; an automatic moving table 30 in. band-saw arranged for cutting cast-iron cylinder blocks for inspection purposes and similar work; an overhead cut-off machine for the high-speed cutting of aluminium extrusions and plastics; and two toolroom machines.

BRITISH JEFFREY-DIAMOND, LTD., Stand D526, include in their exhibits the B.J.D. Flextooth crusher and B.J.D. Swing-hammer pulveriser. The former found wide use during the war in reducing bushy turnings to small sizes for compact storage and easy handling and the pulveriser has been applied to the reduction of bauxite in the "as-mixed" condition for further processing in the production of aluminium.

Laboratory Equipment

Although the scientific instrument section of the B.I.F. is located in London there are a few items of this type on show at Castle Bromwich. On the METROPOLITAN VICKERS ELECTRICAL Co's Stand, C.510, will be seen the latest model of the company's electron microscope, the E.M.3. Electron diffraction patterns are easily obtained

by adjustment of a diaphragm above the first projector lens and adjustment of the first projector lens current. Stereo-micrographs can also be made quite simply on this instrument.

All circuit controls are fitted on a small panel fitted on the control desk and convenient to the operator's left hand. The specimen stage and vacuum controls are placed round the base of the microscope, arranged for easy manipulation. Special care has been taken in designing the E.M.3 to make the work of servicing as simple as possible. All the electronic apparatus is easily accessible, and the microscope may be dismantled without difficulty. After instruction and a little practice it is possible to complete the stripping, cleaning, erection and realignment in about an hour.

The qualitative and dimensional checking of finished components in almost any material is demonstrated on a Cornelius electronic comparator on the WICKMAN stand, D.416. Recent developments have considerably widened the scope of this instrument and a new model now available performs almost any industrial check on ferrous and non-ferrous materials. Examples of material analysis, crack detection, dimensional comparison and surface finish comparison are demonstrated.

Reviews of Current Literature

Films About Metals

Published for The Scientific Film Association by Current Affairs, Ltd., 19, Charing Cross Road, London, W.C. 2., price 3s. 6d. (3s. 8d. post free, 2s. 8d. post free to S.F.A. members.)

A new film catalogue which has been published, has been prepared in conjunction with the Joint Committee on Metallurgical Education, and is the first of a series on specialised subjects which will ultimately replace the "Catalogue of Films of General Scientific Interest" (The Scientific Film Association, price 5s.). Titles of about 200 films are given together with running time, gauge and distributor. Wherever possible, a brief synopsis of content is given and a number of films have been appraised for audience suitability by the expert viewing panels of the S.F.A. A wide field of subjects is covered from the basic metallurgical processes to the utilisation of metals in bridge construction and the manufacture of car bodies.

Hardfacing by Welding

By M. Riddihough, M.Met., A.R.I.C., F.I.M. Published by The Louis Cassier Co. Ltd. D8vo, 127 pages, over 81 illustrations. Price 8s. 6d. (postage 4d.).

Appreciation of the value of hard facing has greatly increased in recent years, largely as a result of the development of processes of applying suitable metals and alloys which increase resistance to wear, corrosion, or both. In this book the author is mainly concerned with hard facing to resist wear. The hard facing metals and alloys are applied by either the electric or oxy-acetylene welding processes, though non-ferrous metals are best applied by means of the oxy-acetylene process.

The repair and replacement of worn parts is especially important in these times when the utmost economy in the consumption of materials must be observed. Especially is this true of machines in which certain key parts are subject to excessive wear, involving their constant repair and replacement. The life of these key parts is infinitely prolonged if the most suitable wear-resisting alloy is welded to the position most subjected to wear; to accomplish this special hard facing rods and techniques have been developed and are described in this book. The information given will assist the welding and maintenance engineer to tackle efficiently the hard facing of such parts.

The book contains chapters on hard facing rods and their development; designing the deposit; designing for specific jobs; characteristics of the metals commonly used for blanks; preheating and cooling; heat treatment for hard facing various types of metals; equipment and jigs for hard facing; hard facing techniques; inspecting machining and grinding the deposit; estimating and planning. Also an Appendix; conversion tables; oxidation and corrosion resistance of some common metals; steel specifications; and details of a number of British and American proprietary hard facing rods.

The book is very practical and it will be noted covers every stage of the process—design of components, choice of hard facing alloy and technique of depositing inspection and finishing methods. As far as the reviewer is aware it is the first to be devoted to this subject and it should be in great demand.—B.S.

Staff Changes and Appointments

Mr. HUGH PERRY has been appointed a Director of Smith's Stamping Works (Coventry), Ltd., Coventry, and Smith Clayton Forge, Ltd., Lincoln. Mr. Perry was until recently Sales Manager of Almin, Ltd., Farnham Royal, Bucks., and a Director of its associate companies, Renfrew Foundries, Ltd., Glasgow; Southern Forge, Ltd., Langley; and Warwick Production Co., Ltd., Warwick.

Mr. DONALD MACBETH, who has for many years served on the Sales Staff of the Morgan Crucible Co., Ltd., has relinquished his post with this firm upon taking up the appointment of Sales Manager with Messrs. T. J. Priestman, Ltd. of Birmingham—Aluminium Alloy Ingot Manufacturers.

Presentation to Mr. Herrington

MR. H. G. HERRINGTON, Director and General Manager of High Duty Alloys, Ltd., was presented recently with a magnificent silver cigarette box on the occasion of his handing over the Chairmanship of the Aluminium Development Association Executive Committee to Mr. F. G. Woollard. Mr. Herrington has held this office since the inception of the Association and was previously Chairman of the Executive Committee of the Wrought Light Alloys Development Association, from which the Aluminium Development Association was evolved.

Mr. Herrington will remain a member of the Council, and in order to ensure minimum disorganisation during the change-over, will retain his seat on the Executive Committee, of which he is the only remaining original member.

IN our last issue we made a brief survey of what we termed the changing face of analytical chemistry, without making any reference to the lines of thought to which this must necessarily give rise. A few points of importance occur to us. In the first place, it seems clear that now is the hey-day of the analytical chemist, and the development of analytical methods has reached a peak of importance comparable to no earlier stage in its history, with the possible exception of the early days of its classical period. Secondly, the relation of analytical chemistry to the rest of the parent science has completely altered. In the old days every chemist had perforce to be his own analyst, and a fundamental and thorough training in the existing methods of analytical chemistry was part of the equipment of every researcher. Fundamental analytical methods are still the best methods of training chemists in certain of the essentials of general chemical practice, but it is not now desirable or, indeed, possible, to ensure that every trained chemist is a competent analytical chemist. The development, indeed, of every branch of chemistry in a like manner precludes anything like competence, and analytical chemistry other than the merest foundations must come after general training. This leads naturally to the next point, which is the problem, even for the highly trained analytical chemist, of assimilating the vast mass of additional knowledge which is flooding in, and which shows no sign of abating. It would be very risky, in the light of the developments of the last ten years, to prophesy just what will fall within the field of the analytical chemist ten years from now. But it is clear that the development period is not yet past. One views with some apprehension the possibility that the future may necessitate further subdivision. Part of the solution will lie in the extensive use of technicians, but whether this will prove a sufficient answer only time will show.

Group Separations in Inorganic Qualitative Analysis

Part III—Miscellaneous Inorganic Reagents

By Francis R. M. McDonnell and Cecil L. Wilson
Microchemistry Laboratory, Chemistry Department, The Queen's University of Belfast

Schemes of inorganic qualitative analysis which do not employ the sulphide ion as a precipitant may be broadly subdivided into two categories, one which employs phosphate as one of the important reagents, and a group of miscellaneous procedures. These schemes are here reviewed.

Phosphate as a Reagent

PETRASCHENJ,[1] in the scheme shown in Table I, first removes tin and antimony by evaporation with nitric acid, and silver and lead with hydrochloric acid. On the addition of ammonium chloride, ammonia and ammonium phosphate to the filtrate from these separations, about half the remaining cations are precipitated as phosphates, while the remainder stay in solution. This phosphate precipitate is then dissolved in hydrochloric acid. Chromium is removed as a soluble sodium salt, and the remainder of the cations are divided into groups using acetic acid and sodium phosphate of definite strengths.

The solution containing the soluble phosphates is further subdivided as shown in Table II. Addition of barium chloride solution to the solution first completes precipitation of aluminium, iron and chromium, and removes excess of the phosphate ion. Excess of barium is then removed with sulphuric acid. Mercury is separated with hydrazine sulphate, copper with ammonium iodide, sodium with concentrated hydrochloric acid, and nickel, cobalt and cadmium with sodium carbonate and hydroxide. Potassium and zinc are left in solution.

Rane and Konlaish[2] precipitate silver, tin and antimony by the addition of hydrochloric acid to the solution for analysis, and evaporation with nitric acid, as shown in Table III. Barium, strontium and lead are then

1 Petraschenj, *Z. anal. Chem.*, 1936, **106**, 330.

2 Rane and Konlaish, *J. Ind. Chem. Soc.*, 1937, **14**, 46.

TABLE I

Evaporate the substance for analysis several times with conc. nitric acid.

- *Residue* Sn, Sb
- *Filtrate* Add hydrochloric acid
  - *Residue* Ag, Pb
  - *Filtrate* Add ammonium chloride, ammonia and ammonium phosphate
    - *Residue* Dissolve in hydrochloric acid. Heat with sodium carbonate and bromine
      - *Residue* Digest with equal parts of 2N acetic acid and 0.5N sodium phosphate
        - *Residue* Dissolve in hydrochloric acid. Evaporate off acid. Digest with acetic acid-sodium phosphate solution
          - *Residue* Treat with 0.5N hydrochloric acid and 0.5N sodium phosphate
            - *Residue* Bi
            - *Filtrate* Al, Fe
          - *Filtrate* Mn
        - *Filtrate* Ca, Sr, Ba, Mg
      - *Filtrate* Cr
    - *Filtrate* Soluble Phosphates. See TABLE II

TABLE II

Make the soluble phosphate filtrate from TABLE I ammoniacal. Add a slight excess of barium chloride solution

- *Residue* Dissolve in hydrochloric acid. Remove barium with sodium sulphate. Test for Al, Fe, Cr
- *Filtrate* Remove excess barium with sulphuric acid. Treat with hydrazine sulphate
  - *Residue* Hg
  - *Filtrate* Acidify and add ammonium iodide
    - *Residue* Cu
    - *Filtrate* Evaporate to dryness. Digest with a little concentrated HCl
      - *Residue* Na
      - *Filtrate* Dilute. Add sodium carbonate and sodium hydroxide
        - *Residue* Ni, Co, Cd
        - *Filtrate* K, Zn

removed as sulphates with ammonium sulphate. Addition of ammonia and ammonium phosphate to the filtrate from this procedure removes a further seven cations, while boiling the filtrate resulting from this

TABLE III

To a solution of the cations add hydrochloric acid. Evaporate with nitric acid

- *Residue* Ag, Sn, Sb
- *Filtrate* Add ammonium sulphate
  - *Residue* Ba, Sr, Pb
  - *Filtrate* Add ammonia and ammonium phosphate
    - *Residue* Al, Cr, Fe, Mn, Bi, Ca, Mg
    - *Filtrate* Add sodium hydroxide
      - *Residue* Cd, Cu, Ni
      - *Filtrate* Zn, As, K

separation with sodium hydroxide precipitates copper, cadmium and nickel. Zinc, arsenic and the alkali metals are left in solution. This method of analysis is stated to offer no advantages other than an escape from the use of hydrogen sulphide.

A third phosphate scheme, shown in Table IV, has been put forward by Khoroshkin,[3] who, after removing the normal Group I chlorides with hydrochloric acid,

TABLE IV

To a solution of the cations add hydrochloric acid

- *Residue* Pb, Ag, Hg
- *Filtrate* Add sulphuric acid and ethanol
  - *Residue* Ca, Sr, Ba, Pb
  - *Filtrate* Add sodium phosphate, ammonia and ammonium chloride
    - *Residue* Mg, Cr, Mn, Sb, Fe, Al, Bi, Sn
    - *Filtrate* Co, Zn, Cu, Hg, Cd, Ni, As, K

precipitates the alkaline earths and the remainder of the lead with sulphuric acid and ethanol. To the filtrate from this precipitation, sodium phosphate, ammonia and ammonium chloride are added, removing eight cations as phosphates or hydrated oxides, and leaving the remainder in solution.

Phosphate schemes suffer from the disadvantage that the phosphate ion interferes with many confirmatory tests, thus restricting their number. This impairs, to some extent, the efficiency of a phosphate scheme as a whole.

Hydroxides

Schemes which dispense with both sulphate and phosphate ions as group reagents depend for the main group separations (apart from the chloride and sulphate groups) largely on the use of hydroxides and carbonates, and the acid-forming properties of certain cations. Several workers have put forward schemes of this nature,

3 Khoroshkin, *Acta. Univ. Voronegiensis* (*U.S.S.R.*), 1939, **10**, No. 4, Sect. Chem. 95; *Chem. Abs.*, 1939, **33**, 8519.

in which, as a preliminary, the chlorides of silver, lead and mercury are removed as usual, the alkaline earths being next precipitated as sulphates.

Lewin[4] treats the filtrate from the sulphate precipitation with potassium hydroxide and hydrogen peroxide,

TABLE V

To a solution of the cations add hydrochloric acid

- *Residue*: Pb, Ag, Hg
- *Filtrate*: Add sulphuric acid
  - *Residue*: Ca, Sr, Ba, Pb
  - *Filtrate*: Add potassium hydroxide till alkaline, and boil with hydrogen peroxide
    - *Residue*: Treat with 0.5N hydrochloric acid, then add excess ammonium bicarbonate
      - *Residue*: Mn, Cr
      - *Filtrate*: Evaporate to small bulk and add ammonia
        - *Residue*: Fe, Ni, Hg
        - *Filtrate*: Mg, Ni, Cu
    - *Filtrate*: Evaporate with hydrochloric acid till acidity is slight. Add sodium carbonate
      - *Residue*: Al, Zn, Sn, Sb
      - *Filtrate*: As, Cr

precipitating seven of the cations. The filtrate is treated with sodium carbonate, precipitating aluminium, zinc, tin and antimony, while arsenic and chromium remain in solution. This scheme is shown in Table V.

Brockman[5] has evolved a very similar scheme, shown in Table VI, which differs only in the division of the potassium hydroxide-hydrogen peroxide residue. A third scheme, due to de Cuto,[6] has the same subdivisions of the cations as in Brockman's scheme.

TABLE VI

To a solution of the cations add hydrochloric acid

- *Residue*: Pb, Ag, Hg
- *Filtrate*: Add sulphuric acid and ethanol. Warm.
  - *Residue*: Ca, Sr, Ba, Pb
  - *Filtrate*: Add potassium hydroxide in excess and boil. Add sodium peroxide and boil
    - *Residue*: Dissolve in HNO_3–HCl. Neutralise with ammonium carbonate. Add ammonia and ammonium phosphate
      - *Residue*: Mn, Fe, Bi, Mg
      - *Filtrate*: Cu, Hg, Co, Ni, Cd
    - *Filtrate*: Sn, Al, Sb, Zn, Cr, As

Munro[7] states that Brockman's scheme, when compared with the classical method, gives better identification for four cations (mercurous, mercuric, arsenic and nickel), equal accuracy for eight, and is less satisfactory for nine. It is, however, more rapid owing to the use of specific confirmatory tests, which entails less subdivision of the group precipitates.

Carbonates

At least five schemes have been evolved which depend principally on the behaviour of certain cations towards the alkali carbonates and hydroxides, and either bromine or hydrogen peroxide. Gerstenzang[8] removes Group I as usual: then the addition of potassium carbonate, potassium hydroxide and bromine precipitates all the remaining cations except antimony, tin, aluminium, and zinc, chromium, arsenic, which are separated by sodium chloride and ammonia. This is detailed in Table VII.

TABLE VII

To a solution of the cations add hydrochloric acid

- *Residue*: Pb, Ag, Hg
- *Filtrate*: Add potassium carbonate, potassium hydroxide and bromine
  - *Residue*: Dissolve in hydrochloric acid and hydrogen peroxide. Add ammonia and hydrogen peroxide
    - *Residue*: Hg, Bi, Mn, Fe, Pb
    - *Filtrate*: Add sodium phosphate
      - *Residue*: Ca, Sr, Ba, Mg
      - *Filtrate*: Add potassium hydroxide and bromine
        - *Residue*: Cu, Cd, Ni, Co
        - *Filtrate*: Discard
  - *Filtrate*: Add sodium chloride and ammonia
    - *Residue*: Sb, Sn, Al
    - *Filtrate*: Zn, Cr, As

A second scheme of this nature, due to Zelada,[9] has a slight modification of reagents, but the division of the cations is identical.

A third scheme, due to Pamfil,[10] follows somewhat similar lines, and is shown in Table VIII. By evaporating the substance to be analysed with nitric acid, antimony and tin are left as residue. Silver, mercury and lead are removed as usual. Bismuth is then separated as the oxychloride, and after the expulsion of ammonia from this filtrate, the addition of potassium hydroxide and hydrogen peroxide precipitates ten cations. From the filtrate aluminium is removed as the hydroxide or phosphate, the alkaline earths as carbonates, zinc as ferrocyanide, chromium as the sodium salt, and finally the addition of ammonia precipitates arsenic and any magnesium not precipitated in the peroxide group.

Roche[11] criticises Pamfil's method, and points out the possibility of other insoluble residues in the nitric acid evaporation, such as silica, titanium dioxide and barium sulphate. In addition, the separation of lead is not complete: this, of course, applies to any scheme of analysis precipitating lead as chloride, but Pamfil does not provide for the treatment of any lead left from the hydrochloric acid treatment. In addition, Roche asserts that silver is liable to be overlooked, and that phosphate would be precipitated before the stage indicated.

4 Lewin, *Z. anal. Chem.*, 1936, **105**, 328.
5 Brockman, *J. Chem. Educ.*, 1939, **16**, 133.
6 de Cuto, *Quim. e ind. (Sao Paolo)*, 1940, **8**, 1601; *Chem. Abs.*, 1941, **35**, 3551.
7 Munro, *Can. Chem. Met.*, 1933, **17**, 240; *Chem. Abs.*, 1934, **28**, 1297.
8 Gerstenzang, *J. Chem. Educ.*, 1934, **11**, 369.
9 Zelada, *Anales asoc. quim. argentine*, 1942, **30**, 29; *Chem. Abs.*, 1942, **36**, 5721.
10 Pamfil, *Mon. Sci.*, 1910 (IV), **24**, ii, 641; *B.C.A.*, 1911, **100**, ii, 1030.
11 Roche, *ibid.*, 1911 (V), **1**, i, 87; *B.C.A.*, 1911, **100**, ii, 1031.

TABLE VIII

Evaporate the substance for analysis several times with nitric acid

- *Residue* Sn, Sb
- *Filtrate* Add hydrochloric acid
  - *Residue* Pb, Ag, Hg
  - *Filtrate* Boil with ammonium chloride
    - *Residue* Bi
    - *Filtrate* Make alkaline with potassium hydroxide and expel ammonia. Dissolve any precipitate formed with hydrochloric acid. Add potassium hydroxide and hydrogen peroxide
      - *Residue* Mn, Co, Ni, Cu, Hg., Fe, Ti, Zr, U, (Mg)
      - *Filtrate* Make acid and saturate with ammonia
        - *Residue* Al
        - *Filtrate* Make acid. Add ammonium carbonate
          - *Residue* Ca, Sr, Ba
          - *Filtrate* Make acid. Add one drop potassium ferrocyanide
            - *Residue* Zn
            - *Filtrate* Add hydrogen peroxide and ether
              - *Residue* Cr
              - *Filtrate* Add ammonia
                - *Residue* As, Mg
                - *Filtrate* Discard

TABLE IX

To a solution of the cations add potassium hydroxide and potassium carbonate

- *Residue* Dissolve in nitric acid and hydrogen peroxide. Add stannic hydroxide. Evaporate solution to dryness. Extract with acid
  - *Residue* Si, P, As, Sb
  - *Filtrate* Make strongly alkaline and boil with hydrogen peroxide
    - *Residue* Fe, Bi, Mn
    - *Filtrate* Add ammonium oxalate
      - *Residue* Treat with acetic acid
        - *Residue* Fe, Bi, Mn
        - *Filtrate* Ca, Sr, Ba
      - *Filtrate* Add hydrazine sulphate
        - *Residue* Ag, Hg
        - *Filtrate* Add ammonium thiocyanate
          - *Residue* Cu
          - *Filtrate* Cd, Ni, Co, Mg
- *Filtrate* Divide in two parts
  - Portion 1 Acidify. Test for Sb, As, Sn
  - Portion 2 Add sodium sulphide
    - *Residue* Pb, Zn, Cr
    - *Filtrate* Al, Cr, As, Sb, Sn

The last two schemes, due to Almkvist[12] and Macchia[13] are most easily described diagrammatically. That due to Almkvist is shown in Table IX, while Macchia's procedure is given in Table X.

TABLE X

Boil with aqua regia, concentrate, add nitric acid and concentrate further. Cool and make alkaline with ammonia, disregarding incomplete solution. Add ammonium carbonate and hydrogen peroxide, and boil. Add more ammonium carbonate and then ammonia

- *Residue* Boil with concentrated nitric and hydrochloric acids. Evaporate to small bulk. Add freshly prepared 50% sodium hydroxide solution. Boil with several portions of sodium peroxide. Dilute with saturated sodium carbonate solution and filter immediately
  - *Residue* Heat with acetic acid. Boil gently with concentrated nitric acid
    - *Residue* Discard
    - *Filtrate* Concentrate and then dilute with a large volume of water. Add ammonium chloride, make alkaline with ammonia, and heat with hydrogen peroxide
      - *Residue* Mn, Fe, Bi
      - *Filtrate* Mg, Ca, Sr, Ba
  - *Filtrate* Pb, Cr, Al, Sn, Sb
- *Filtrate* Ag, Hg, As, Li, Na, K, Cr, Co, Ni, Cd, Zn, Cu

12 Almkvist, *Z. anorg. allgem. Chem.*, 1918, **103**, 221.
13 Macchia, *Notiz. chim. ind.*, 1927, **2**, 191; *Chem. Abs.*, 1927, **21**, 2625.

(To be concluded)

Development of South Africa's Chemical Industry

The recent news that African Explosives and Chemical Industries (Pty.), Ltd., were reported to be erecting a nitrogenous fertiliser plant, at an estimated cost of £2,000,000, would appear to have some connection with the announcement that The Power-Gas Corporation, Ltd., of Stockton-on-Tees, have received a contract for extensions to an existing gas-making plant for a South African industrial company.

This last contract for South Africa brings the grand total of Power-Gas installations of large automatically-operated water-gas units, with mechanical ash extraction in hand or installed by them for industrial use, as distinct from the domestic gas industry, to 118. This present contract is similar in many respects to the gas-making sections of other current contracts held by The Power-Gas Corporation, Ltd., for fertiliser plant for the Government of India and for the M.E.K.O.G. Organisation of Holland, and will incorporate several modern developments, including their adaptation of the well-known Lockheed Hydraulic Equipment for the cyclical operation of gas-making plant.

It is believed that, when the South African Scheme is completed, output of ammonia from extensions to the Modderfontein Works will reach 26,000 short tons per annum, which, with existing capacity, is expected to make the Union self-supporting for fixed nitrogen.

New Precision Casting Process

By Herbert Chase, in collaboration with L. T. Schakenbach

THE latest casting process is a variation of precision casting in which frozen mercury replaces the wax generally used in investment casting. The method is patented and is known as the Mercast process. The use of frozen mercury offers greater dimensional accuracy, superior smoothness and accuracy of detail.

The normal procedure is modified for this process, because the mercury pattern must be chilled to below –40° C. to solidify and hold its shape until investment is completed. The process is carried out as follows :—

The mould for making the pattern is built much the same as for wax but with a different allowance for shrinkage and with a sprue hole or holes formed within the mould in place of the injection opening used for wax. When assembled, the mould is placed on a bench and is first filled with acetone, which acts as a lubricant. Then mercury at room temperature is poured into the mould from a beaker and displaces the acetone.

When thus filled, the mould is placed in a cold tank for freezing. This tank has 10 in. of cork insulation on the sides and 12 in. on the bottom. The top is open along two sides of a central box containing dry ice, but this box is kept covered. The box, which is of stainless steel, has its lower portion immersed in methylene chloride to a depth of about 24 in., the liquid being under as well as around the box and having a depth of 28 in. around the box. This liquid is non-flammable and non-toxic, and is chilled by the dry ice in the box to –61° C.

In this cold liquid, the mould is nearly submerged, resting on a platform, until the mercury freezes. A bent wire rod placed in the sprue hole freezes in the mercury and provides a convenient means for handling the pattern. As the mercury contracts somewhat in freezing, more mercury is sometimes added while freezing proceeds. Suitable allowance is made for the shrinkage of the metal to be cast, of course, in designing the mould, but no shrinkage allowance is required for the mercury itself. In general, it takes about 10 min. for the pattern to freeze. Then the mould is opened by an operator using gloves while the mould rests on a wooden platform that is barely submerged in the refrigerant.

As the pattern, which looks like and is about as hard as lead, must be kept frozen and free of moisture condensed from the atmosphere, each pattern is immediately submerged, suspended from the wire handle until ready for investing, which is done in another cold tank. This tank is also cooled by dry ice but containing no other refrigerant. In a larger tank are small containers for the liquid investing slurry, which is kept at about –60 C., or well below the freezing point of the mercury.

When dipped in the slurry (Crytobalite), the pattern, held by the wire in gloved-hands, is tilted and turned until all surfaces are coated. Then the pattern is left to drain for about 15 to 30 min., during which other patterns are being similarly coated. Thereafter, the pattern is redipped several times at about 15–30 min. intervals until a satisfactory thickness of coating is built up.

In general, 8–12 dips are enough to provide a shell of sufficient strength, say from $\frac{1}{8}$–$\frac{1}{4}$ in. average thickness. If, especially for large moulds or those to be cast centrifugally, greater mould strength is desired, the shell formed by dipping can be set in a supporting investment in a flask before baking is done.

The mix used in the dipping investment includes solid refractory ingredients, and the smoothness of the inner wall of the investment (which contacts the metal to be cast) affects the smoothness of the casting. For greatest smoothness, the pattern must be smooth and the refractory particles as small as feasible.

Draining off the Mercury

When the dipping investment is complete, the mould thus formed is placed on a bench where heat is absorbed from the atmosphere. This results in the mercury becoming liquid and it flows out and to the drain hole at the centre of the bench, passing thence through a water seal into a container from which the mercury is passed through a cleaning cascade. The mercury is thus cleaned of any refractory or impurities and is collected in bottles for re-use.

As the mercury never attains a temperature above that of the room and is never touched by hands, the chances of mercury poisoning are considered negligible.

When the moulds are free of mercury, they are dried at 90 C., fired at about 1,030 C., and then cooled to the temperature best suited for the alloy to be cast in the moulds, much as for moulds made with wax patterns. Casting is also done with the same equipment.

Advantages attained with the mercury patterns include smoother surfaces, less pattern distortion, ability to attain sharper corners and thinner sections at edges, ability to hold significantly closer dimensions, and feasibility of using larger patterns than for those made in wax. Important results include more precise dimensions and smoother surfaces on castings if pattern mould cavities are polished sufficiently.

Dimensional limits have been held within —0.003 in. for dimensions up to $1\frac{1}{2}$ in. and, on some smaller dimensions, limits as close as —0.001 in. have been held at certain critical points in making aluminium castings.

In general, the Mercast process has been found to enable closer control on critical dimensions than when wax patterns are used—but, processing has been somewhat slower and costs higher than where wax has been used. As yet, experience with the process has been limited and further experience may alter such conclusions as have been drawn.

From *Materials and Methods*, 1949 **29** pp. 52–56.

Manufacture in German Factories of Steel Strip Bonded with Aluminium

STEEL, bonded with aluminium and marketed under the trade name of Feran was utilised in Germany for bands for electric cables for heating equipment, for diaphragms for telephones, for the windings for flexible piping, etc. The product was manufactured principally by the Wickede Eisen und Stahlwerke at Wickede (Ruhr) and by the Trierer Walzwereke at Treves (French Zone) and at Langerfeld Wuppertal (English zone). The total production of these three factories, before the war, was about 500 tons per month.

The manufacturing procedure utilised by the Wickede Eisen und Stahlwereke (the other factories also used similar methods) consisted in a mechanical operation followed by a thermal treatment so as to alloy the steel and the aluminium in an intimate manner.

The steel utilised was an excellent deep drawing quality material, of the following composition: C, 0·06; S, 0·04; P, 0·04; Mn, 0·6; Si traces.

The aluminium which contained from 0·6 to 1 Si and 0·35 Fe was supplied in strip 150 mm. wide and 6 mm. thick. These were cold rolled down to 0·2 mm., sheared to the desired width, heat treated in coiled bands, rough brushed and then coiled on special holders which were mounted on the bonding roll stand, below and above the steel strip.

The steel was delivered in the form of hot rolled strip, 150 mm. in width and 3·50 mm. thick; it was pickled in cold hydrochloric acid or warm sulphuric acid, washed with cold water, then passed through a warm milk of lime bath. After rinsing and drying, the strip was straightened on a seven roll roller straightening machine and was then passed immediately through the brushing machine which was composed of four sections, each one composed of a circular brush and a conveying roll, placed alternately one above the strip and the other below. The revolving circular steel brushes were fitted with steel wire of a high carbon content and being 80–100 mm. in length and 0·6–0·6 mm. diameter, when new. Phosphor bronze wires could also be used.

When the brushed steel strip had received a roughened surface they were rolled on a double or four mill stand, equipped with coils of aluminium. The shafts of the coil holders were provided with Ferodo lined brakes, to provide the requisite tension on the metal strip. The aluminium passed on to two small guide rolls, parallel to the main rolls and placed near to these, before being roll-laminated with the steel.

The lamination was affected with the maximum possible elongation, so as to provoke mechanically an adherence maintained by a very close rolling pass on the stand. The thickness reduction in one pass should be at least a minimum of 40 per cent.

The mill stand was driven by a very powerful electric motor. The temperature necessary to obtain a good lamination is from 100–200 C.; this temperature is produced and maintained by the work performed during cold rolling and not by a separate heating.

On leaving the rolls, the aluminium-steel-aluminium strip is coiled up under a high tension. After the laminating rolling, the metal is subjected to a further cold rolling on a mill stand of normal construction down to the final thickness, without any preliminary or intermediate heat treatment.

The laminated strip is then heat treated at a temperature varying between 535° and 550° C. and which should be maintained within the limits of ±5° C., according to the weight of the charge; this is usually of the order of 1,000–1,800 kg., and the duration of the heat treatment is from 10–15 hours. The temperature and the time are a function of the two factors, the maximum for the ductility of the steel and the minimum for the formation of $FeAl_3$ at the contact faces of the metals.

Fused Ore for the Openhearth

By E. S. Kopecki

A CONTINUOUS fusion process, using iron ores of any degree of fineness as raw material, the product of which is suitable for both open hearth charge and feed ore and blast furnace charge, has been developed for the Great Lakes Steel Corp. Based on a French method known as the Follsain process, which is claimed to have never been developed successfully, the fused ore technique has been carried out at Hanna Furnace Co. in a rotary kiln. The ore and fuel bins, fuel being either coke breeze or anthracite coal, are constructed in such a manner that their contents are fed onto a belt conveyer with table feeders. The belt conveyer discharges into a pug mill for mixing and the mixture is discharged into a bucket elevator and lifted to a chute down which it passes by gravity to the rotary kiln.

The charge passes down the kiln, and when within 3–5 ft. of the discharge end, a blast of air, preheated to approximately 710° C., is directed downward on the preheated charge at a sufficient pressure to agitate the material through the depth of its bed. The preheated air striking the preheated ore and fuel generates almost instantly a temperature sufficiently high to fuse the ore. The products of combustion passing up the kiln preheat the ore and fuel as the latter moves down the kiln.

Adjacent to and paralleling the lining of the kiln, there is permanently located a water-cooled steel knife-edge, which cuts from the lining any partially fused ore adhering to the lining. Pieces of semifused ore, scraped from the lining by the cutterbar, drop back into the fused, or semifused ore, and so build up into sizes suitable for openhearth use.

An alternative procedure is to completely fuse the ore by the addition of a slight excess of fuel so that the ore leaves the kiln in liquid form and solidifies in the pan conveyor to the size and shape of the pans used. From the pan conveyer the ore passes over a series of screens to separate it into different sizes: Over 4 in. is considered as openhearth feed ore; between 4 and 1 in. as openhearth charge ore; between 1 and $\frac{1}{8}$ in. as blast furnace ore; and under $\frac{1}{8}$ in. as returned fines (the latter occurs during interruptions to the process, caused by stoppages).

An externally-fired recuperator is used for preheating the blast. The most economical fuel in a steel plant would be blast furnace gas. Instruments record the temperature of the air blast and the temperature of the exhaust gases (the latter temperature averages 260° C.). Pyrometer couples are inserted throughout the length of the kiln at 10 ft. intervals and temperatures recorded hourly to show the preheating stage arrived at as the material passes down the kiln.

From *The Iron Age*, **163**, No. 14, 83-86.

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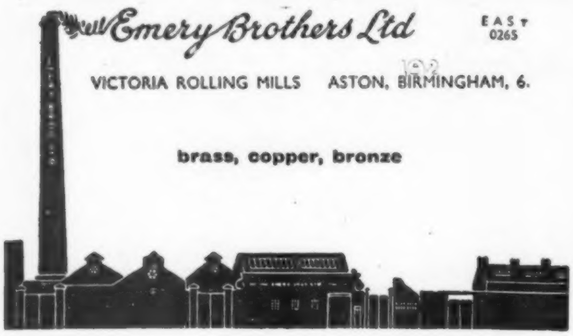

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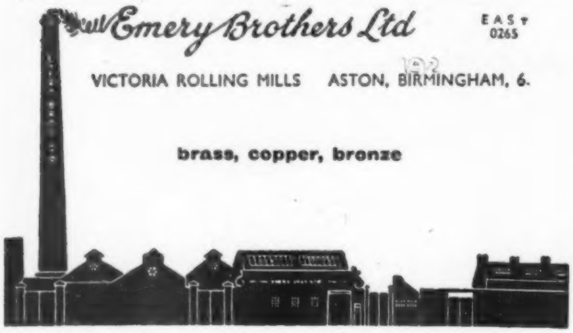

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